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GENERAL DESIGN SPECIFICATION

TOTAL OZONE MAPPING SPECTROMETER

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A	Added ADEOS electrical interface requirements, eliminated all Perkin Elmer TBDs, reduced GSFC TBS requirements to one and updated tables and figures to latest instrument design.	All		
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1. **SCOPE.**

1.1 **General.** This specification establishes the general requirements for the Total Ozone Mapping Spectrometer (TOMS) and its major components, and is the main systems-engineering tool for the TOMS program. This document shall be the primary technical specification for the TOMS FM-3 and later instruments, not including ground support equipment. It conforms to the requirements of the TOMS technical specification GSFC TOMS-910-90-001 as negotiated.

This specification follows the format of MIL-STD-490, Appendix VII, "Prime Item Product Function Specification".

1.2 **Classification.** This document specifies the requirements for one engineering, one structural-thermal, and various flight models, as shown in Table 1.

Table 1. TOMS Instrument Part Numbers

Model	Spacecraft	Assembly Drawing Number	Interface Control Drawings (ICD)
Structural-Thermal Model	N/A	371100	371103
Engineering Model	N/A	371200	371203
Flight Model 3 (FM-3)	Earth Probe	371300	371303
Flight Model 4 (FM-4)	ADEOS	371400	371403
Flight Model 5 (FM-5)	Earth Probe	371500	371503

1.2.1 **Structural-Thermal Model.** The structural-thermal model shall meet the mechanical and interface envelope, thermal interface, and weight requirements of the FM-4 flight model.

The STM shall have a representative thermal radiator that is flight-like in size, structural attachment, weight, and optical properties. The STM shall be equipped with electrical heaters the power to which shall be externally controlled by changing the voltage to the heaters. These heaters shall have sufficient capacity to simulate the hot-case fluxes from the sun, earth and spacecraft as well as the heat generated in the TOMS that is to be radiated from this radiator.

1.2.2 **Engineering Model.** The engineering model shall be in the same configuration as TOMS FM-4, shall meet all functional requirements of this specification with the ADEOS spacecraft interface, and shall pass an acceptance-level random vibration test specified herein, but shall not use screened parts and is not required to meet the optical performance requirement.

1.2.3 **Flight Models.** The flight models shall meet all requirements of this specification and shall pass the flight-acceptance-level environmental tests specified herein. TOMS FM-3 shall be a protoflight model and shall pass the qualification-level environmental tests specified herein.

2. APPLICABLE DOCUMENTS.

2.1 Government.

2.1.1 National Aeronautics and Space Administration.

GSFC TOMS-910-90-001, Rev. 1, Total Ozone Mapping Spectrometer, Technical Specification, July 23, 1990.

GSFC 303-TOMS-002, Performance Assurance Requirements for TOMS Instruments, June 1989.

GSFC S-311-P-18, Thermistor, Insulated, Negative Temperature Coefficient.

GSFC Ref. Pub. 1124, Revision 2, Outgassing Data for Selecting Spacecraft Materials.

Radiation Environment for the TOMS Mission, EnviroNET - The Space Environment Information Service, Goddard Space Flight Center, April 1991.

PPL-19, GSFC Preferred Parts List.

NHB 5300.4(3A-1), Requirements for Soldered Electrical Connections.

NHB 5300.4(3G), Requirements for Interconnecting Cables, Harnesses, and Wiring.

NHB 5300.4(3H), Requirements for Crimping and Wire Wrap.

NHB 5300.4(3J), Requirements for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies.

NHB 5300.4(3K), Design Requirements for Rigid Printed Wiring Boards and Assemblies.

2.1.2 Military Standards and Specifications.

DOD-D-1000B, Military Specification, Drawings, Engineering, and Associated Lists, Levels 1, 2, and 3, 1983.

DOD-HDBK 263, Electrical Discharge Handbook for Protection of Electrical and Electronic Parts.

DOD-STD-1686, Electrostatic Discharge Program for Protection of Electrical and Electronic Parts.

MIL-P-55110D, Requirements for Printed Wiring Boards, 31 December 1984, and Amendment 4, 2 December 1990.

MIL-STD-461C, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference, 4 August 1986, as amended by Notice 1, 1 April 1987.

MIL-STD-462, Electromagnetic Interference Characteristics, Measurement of, 31 July 1967, as amended by Notice 1, 1 August 1968.

2.1.3 **Federal Standards.**

FED-STD-101C, Test Procedures for Packaging Materials.

FED-STD-209, Clean Room and Work Station Requirements, Controlled Environment.

2.2 **Perkin-Elmer Documents.**

080086-460, TOMS Instrument Firmware Design Specification

371100, Structural-Thermal Model, Assembly Drawing

371103, Interface Control Drawing, TOMS STM

371200, Engineering Model, Assembly Drawing

371203, Interface Control Drawing, TOMS EM

371300, Flight Model 3, Assembly Drawing

371303, Interface Control Drawing, TOMS FM-3

371400, Flight Model 4, Assembly Drawing

371403, Interface Control Drawing, TOMS FM-4

371500, Flight Model 5, Assembly Drawing

371503, Interface Control Drawing, TOMS FM-5

38-0700, Chopper Brushless DC Motor/Encoder Assembly Product Specification

38-0701, Product Specification for Three-Degree Stepper Motor (Area Scanner)

38-0703, Product Specification for Three-Degree Stepper Motor (Diffuser Drive)

39-0366, Product Specification Photomultiplier Tube Assembly

54-0040, Lubrication of Ball Bearings, Procedure for, 26 July 1991.

65-0064, Product Specification of Brushless DC Motor Commutator/Tachometer Encoder

65-0070, Optical Subsystem Design Specification

65-0075, Reflectance Calibration Subsystem Design Specification

71-0092, Design Specification TOMS Electronics Module (ELM)

71-0180, Photomultiplier Tube Electrometer Design Specification, TOMS

71-0182, High Voltage Power Supply Design Specification, TOMS

71-0183, Voltage-to-Frequency Converter Design Specification, TOMS

71-0184, Electronic Calibration Subsystem Design Specification, TOMS

71-0185, Chopper Servo Design Specification, TOMS

71-0186, Lamp Power Supplies Design Specification, TOMS

71-0187, Stepping Motor Encoders Subsystem Design Specification, TOMS

71-0188, Housekeeping Subsystem Design Specification, TOMS

71-0189, Low Voltage Power Supply Design Specification, TOMS

74-0023, Performance Assurance Implementation Plan, 1 January 1991.

74-0024, Configuration Management Plan for TOMS FM 3-5, Issue 1, 8 February 1991.

30065-24000-02A, Wavelength Monitor Subsystem DFM.

2.3 **Spacecraft Interface Documents.** TRW, IF3-0007, TOMS-EP Spacecraft Bus to Instrument ICD. NASDA, NASDA-ESPC-01183, TOMS-ADEOS Interface Control Specification.

3. REQUIREMENTS.

All requirements of this section shall be verified by test, inspection or analysis.

3.1 **Instrument Definition.** The Total Ozone Mapping Spectrometer instrument(s), hereinafter referred to simply as TOMS, shall provide intensity measurements of the incident solar spectral irradiance and of the spectral radiance of the atmosphere in six specified near-ultraviolet wavelength bands from low earth orbit, using the reflected sunlight from diffuser plates as a reference. The spectral intensity shall be measured with high differential radiometric stability to allow precise detection of trends in the global total ozone distribution.

3.1.1 **Instrument Diagrams.** To assure the correct order of precedence, figures referred to in this specification shall not be made into separate applicable documents, regardless of size, unless they are Class I documents under separate configuration control.

3.1.1.1 **Instrument Concept.** The TOMS measures the radiation reflected from earth or a selectable reference diffuser by means of a scan mirror and grating monochromator as shown in Figure 1. Light from the scene passes through a depolarizer and entrance lens, and then enters the monochromator. Slits on a rotating optical chopper sequentially select one of six wavelength bands for detection by a photomultiplier detector. A mercury lamp provides a wavelength repeatability monitor, while a separate mercury-phosphor lamp provides a transfer standard for calibrating diffuser reflectance.

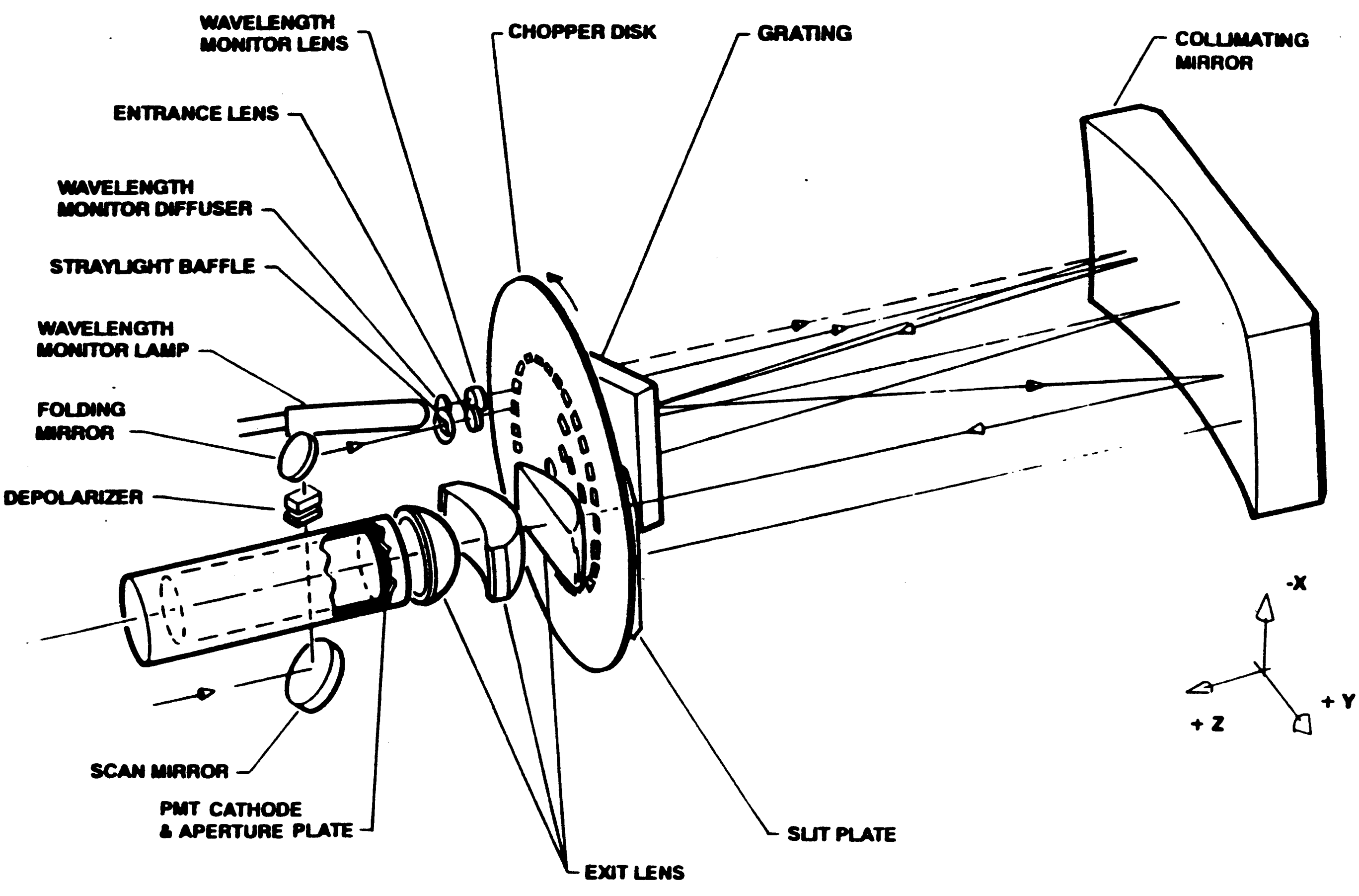

Figure 1. Instrument Concept.

3.1.1.2 **Functional Block Diagram.** The TOMS shall have the functional subsystems and major components shown in Figure 2.

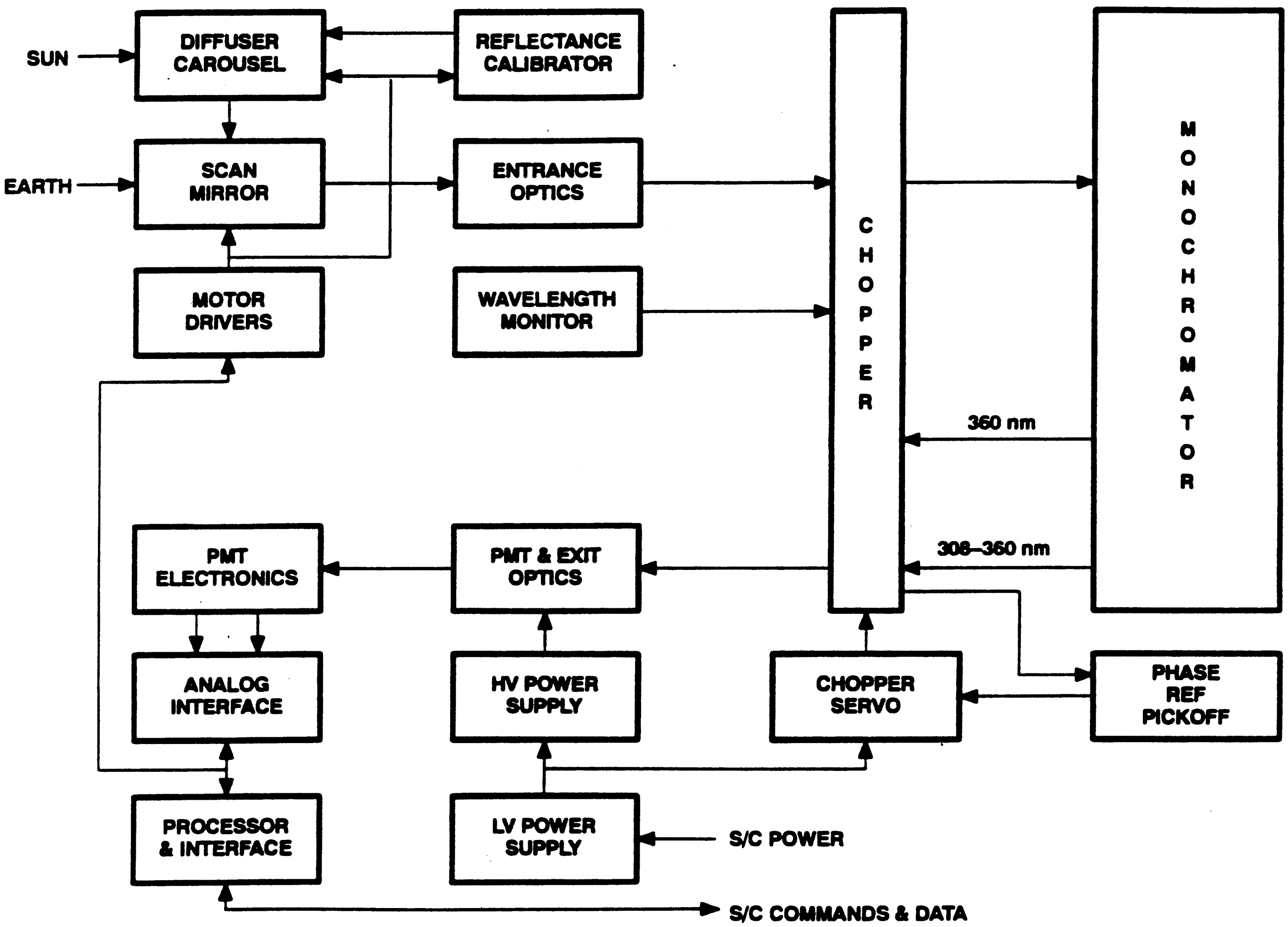

Figure 2. Functional Block Diagram.

3.1.1.3 **Exploded View.** Figure 3 shows the physical breakdown of the TOMS hardware, defining the major assemblies and nomenclature. The instrument optics module consists of three major components: the monochromator with its slit and grating assembly, the lower housing, which contains the scanner, chopper, diffuser, wavelength monitor lamp, and the critical signal-processing electronics. The digital and less critical analog electronics are mounted on the supporting pedestal. For historical reasons, certain components are still collectively referred to as the Electronics Module, namely the Digital I/O, Microprocessor, Motor/Heater Driver, and the Low Voltage Supply, although there are four distinct circuit modules. The other modules shown support the Optics Module: the Analog Interface, Motor Control, and Lamp Power Supply.

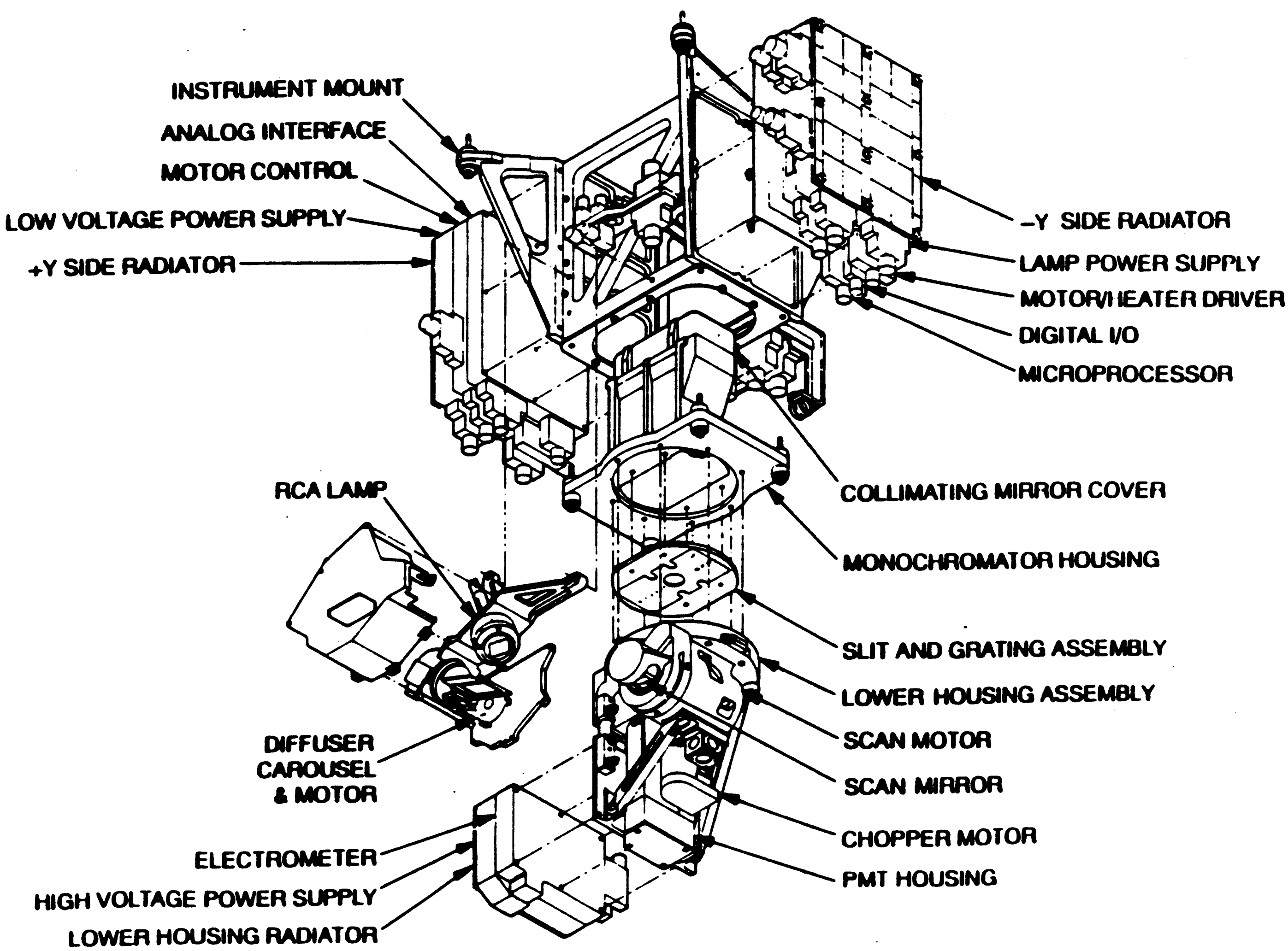

Figure 3. Exploded View.

3.1.2 **Interface Characteristics.** This section defines the interfaces between the TOMS instrument and the spacecraft and between the major components of the TOMS.

3.1.2.1 **Spacecraft Adaptation.** All mounting and interfacing with the designated spacecraft shall be in accordance with the appropriate Interface Control Document (ICD) referenced in Table 1. The TOMS instruments shall be of a standard design, adapted to various spacecraft by means of (where needed) a diffuser adapter, an electronic adapter, and PROM firmware. The mission-specific characteristics of the adapters shall be as specified in the applicable ICD.

a. **Diffuser Adapter.** To allow for different sun angles on different orbits, different diffuser mounts may be used for different spacecraft.

b. **Electronic Adapter**. To allow for different spacecraft electrical interfaces, the TOMS may include an electronic adapter having standard interfaces with internal circuits, but with spacecraft interfaces depending on the spacecraft to be used. Unless absolutely necessary, the electronic adapter shall not be a physically separate unit, but rather one or more TOMS subassemblies or circuit boards that can be replaced with others having identical internal mechanical and electrical interfaces but different spacecraft interfaces.

c. **PROM Firmware.** TOMS internal operations and timing shall be controlled by software stored in a PROM. All mission-specific timing and other changes shall be implemented by PROM firmware and parameter uploads only.

3.1.2.2 **Mounting and Clear Fields of View (CFOV).** Each TOMS instrument shall be mounted to its spacecraft with a clear nadir-facing field of view for the scanner, a clear view of the sun for the diffuser plate, and a clear view of cold space for the radiation cooler(s). The TOMS coordinates and clear fields of view shall be as defined in the applicable Interface Control Drawing (371203 - 371503). For reference, see Figures 4A, 4B and 4C. The fields of view shown are larger than the actual fields of view to allow for tolerances and out-of-field response. The TOMS mounting plane shall be perpendicular to the nadir direction with the scan plane oriented perpendicular to the nominal spacecraft velocity vector. To assure that the diffuser has a clear view of the sun, the instrument shall be mounted on the spacecraft with the sun predominantly on the -Y side as follows:

a. If the orbit has a PM ascending node, the instrument +X axis shall be in the direction of the nominal spacecraft velocity vector (instrument faces forward). Solar calibration shall occur over the northern hemisphere at instrument dawn.

b. If the orbit has an AM ascending node, the instrument -X axis shall be in the direction of the nominal spacecraft velocity vector (instrument faces backward). Solar calibration shall occur over the southern hemisphere at instrument sunset.

Note that the sun vector (shown for a PM ascending node) is in the position shown in Figures 4A, 4B and 4C only when the spacecraft is over the terminator at which solar calibration occurs. During the rest of the orbit the sun vector moves in a cone about the Y-axis, and is obscured at night. All faces of the instrument may see the sun, but the +Y face is usually shaded.

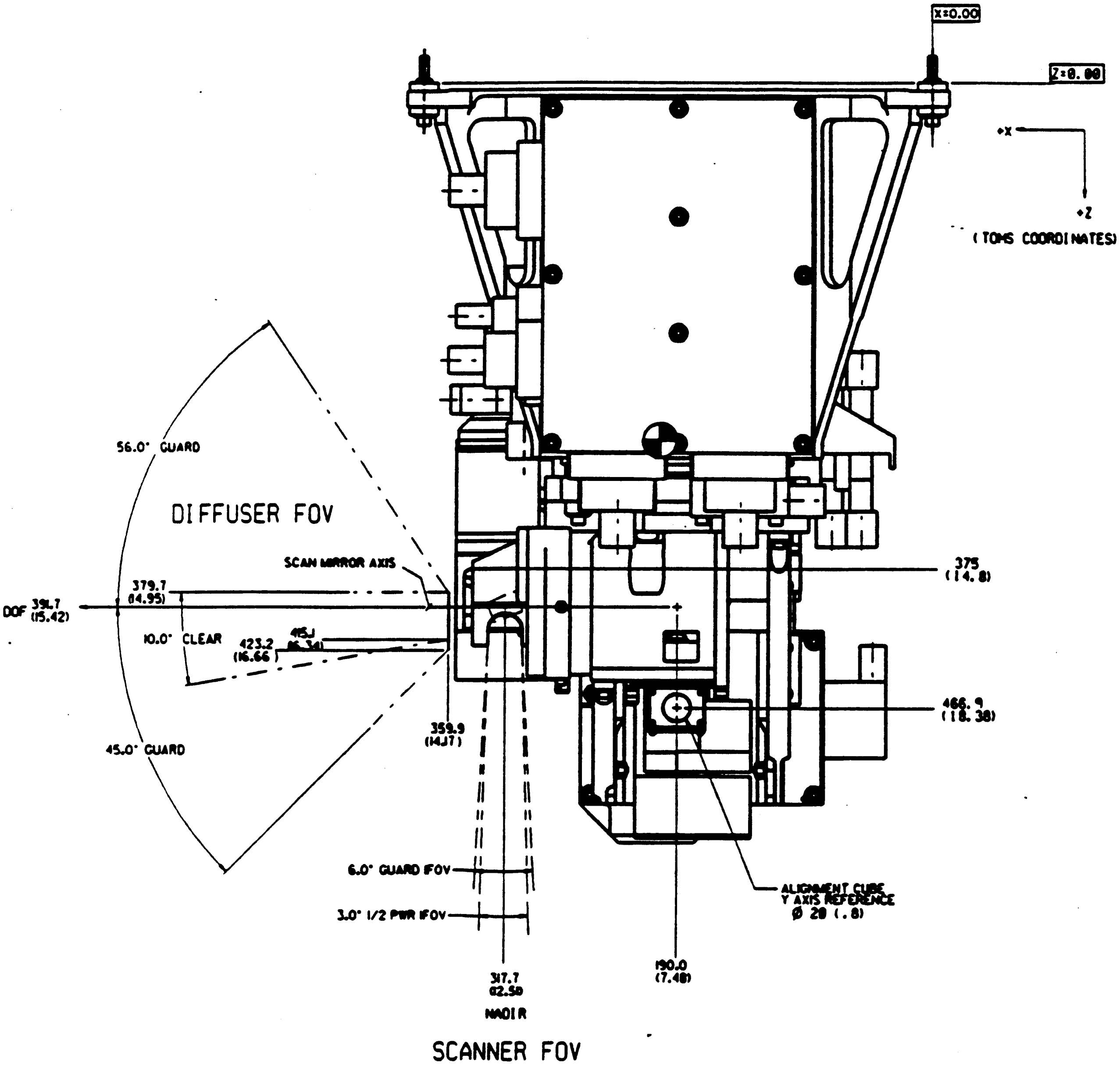

Figure 4A. Clear Fields of View (For Reference Only).

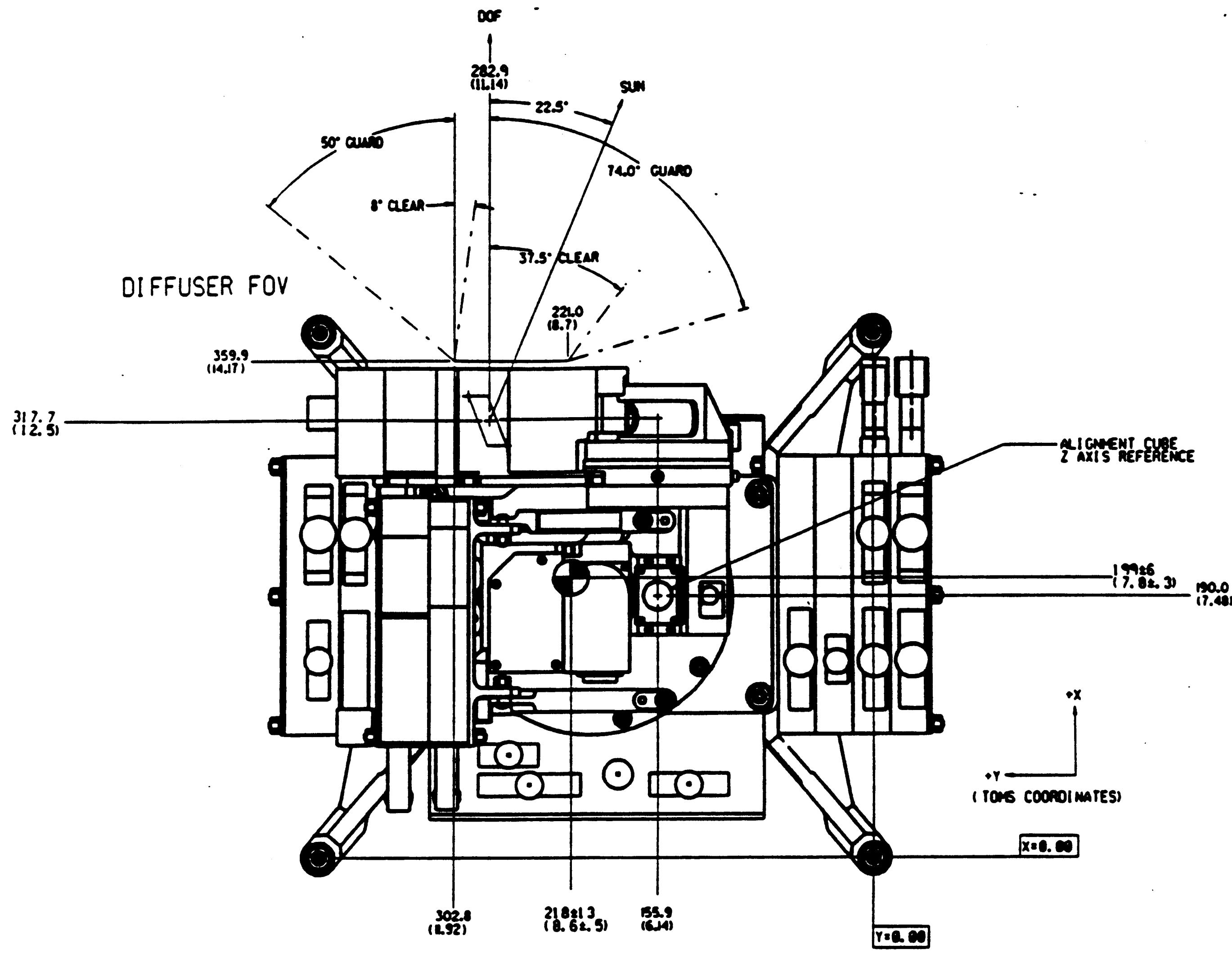

Figure 4B. Clear Fields of View (For Reference Only).

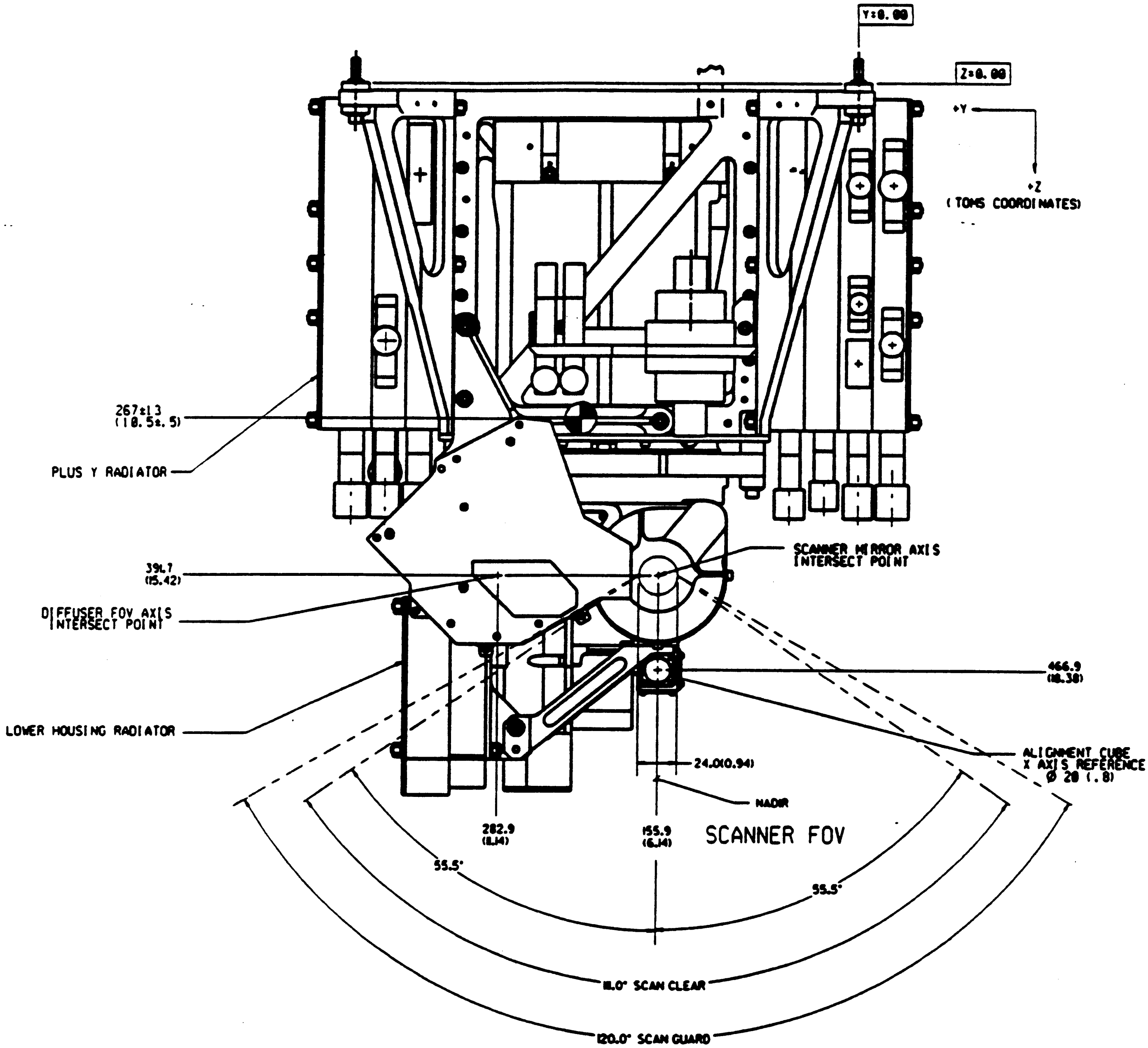

Figure 4C. Clear Fields of View (For Reference Only).

3.1.2.2.1 **Center of Gravity.** The location of the center of gravity shall be approximately as shown in figures 5A, 5B, and 5C.

3.1.2.2.2 **Scanner Fields of View.**

Clear Field of View: The angular extent of a region that is projected from a given point or surface and is required to be clear for unobstructed viewing by the instrument.

Guard Field of View: The angular extent defined from a reference point or area that must not contain a surface or other source that in the normal modes of operation of an optical system introduces spurious radiation or scattered light into the field of response of the system.

The scanner shall have a clear field of view in a plane perpendicular to the spacecraft roll axis (nominal velocity vector) centered at nadir, as shown in Figures 4A, 4B and 4C. Note that although the instantaneous field of view (IFOV) is square, it rotates with scan angle, so that the CFOV must be circular. Origins of the scanner CFOV shall be as shown in Table 2.

3.1.2.2.3 **Diffuser Fields of View.**

Clear Field of View: The angular extent of a region that is projected from a given point or surface and is required to be clear for unobstructed viewing by the instrument.

Guard Field of View: The angular extent defined from a reference point or area that must not contain a surface or other source that in the normal modes of operation of an optical system introduces spurious radiation or scattered light into the field of response of the system.

The diffuser clear field of view shall be within the envelope shown in Figures 4A, 4B and 4C. The normal to the diffuser may be offset by an azimuth bias in the X-Y plane to allow for the mean sun angle. Origins of the diffuser CFOV shall be as shown in Table 2.

3.1.2.2.4 **Radiator Clear Field of View.**

Clear Field of View: The angular extent of a region that is projected from a given point or surface and is required to be clear for unobstructed viewing by the instrument.

Radiators shall be shaded from the sun and have average diffuse view factors to the spacecraft that shall not exceed 0.50. The origins of the radiator CFOVs shall be as shown in Table 2 if not overridden by the applicable ICD.

Table 2. FOV Areas and Origins
Measurements in TOMS coordinates in centimeters (inches)

Item	Area cm^2 (in^2)	X Origin	Y Origin	Z Origin
Scanner CFOV	0.7 (4.2)	318 (12.5)	156 (6.1)	391.7 (15.42)
Diffuser CFOV	17.0 (2.6)	318 (12.5)	283 (11.1)	391.7 (15.42)
+Y Radiator CFOV	469.1 (72.7)	190 (7.5)	428 (16.8)	147 (5.8)
Lower Housing Radiator CFOV	212.9 (33.0)	203 (8.0)	356 (14.0)	480 (18.9)

3.1.2.2.5 **Mounting Footprint and Envelope.** The mounting footprint and envelope of the TOMS shall be as shown in Figures 5A, 5B, and 5C.

3.1.2.3 **Alignment.** Alignment of the instrument and its components shall be as follows.

3.1.2.3.1 **Instrument Alignment.** Provision shall be made for alignment mirrors aligned within ±0.25 degree to the scanner rotation axes (nominal directions same as instrument axes in Figures 4A, 4B and 4C). The alignment of the mirrors relative to the instrument axes shall be measured to 0.05 degrees rms. See notes in Section 6.

3.1.2.3.2 **Scanner Nadir Alignment.** The nadir direction of the scanner (roll axis position) shall be aligned with the spacecraft nadir direction defined by the alignment mirrors with an accuracy of 0.25 degree and shall be measured to ±0.05 degree.

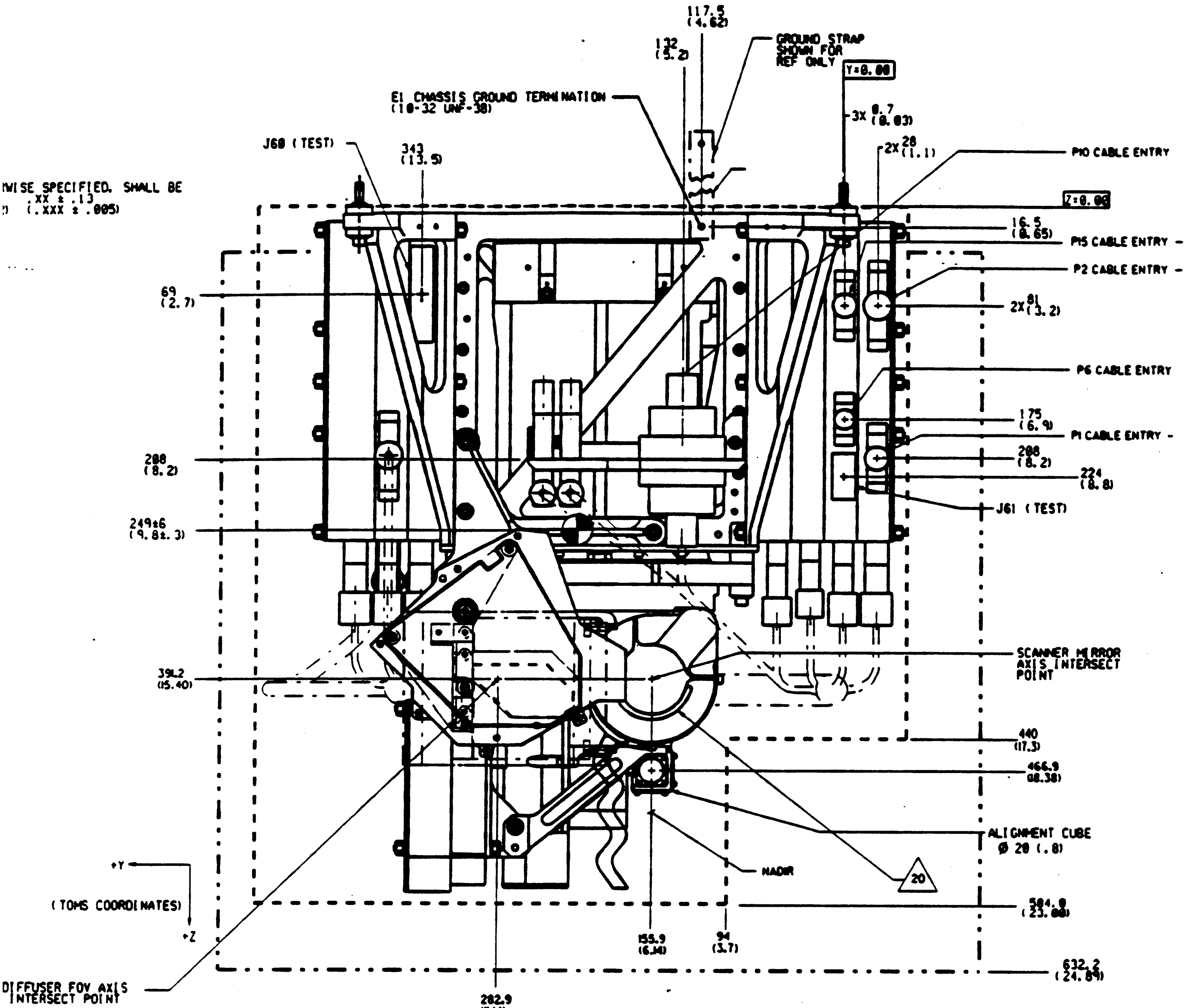

Figure 5A. TOMS Envelope and Mounting (X-View; for reference only).

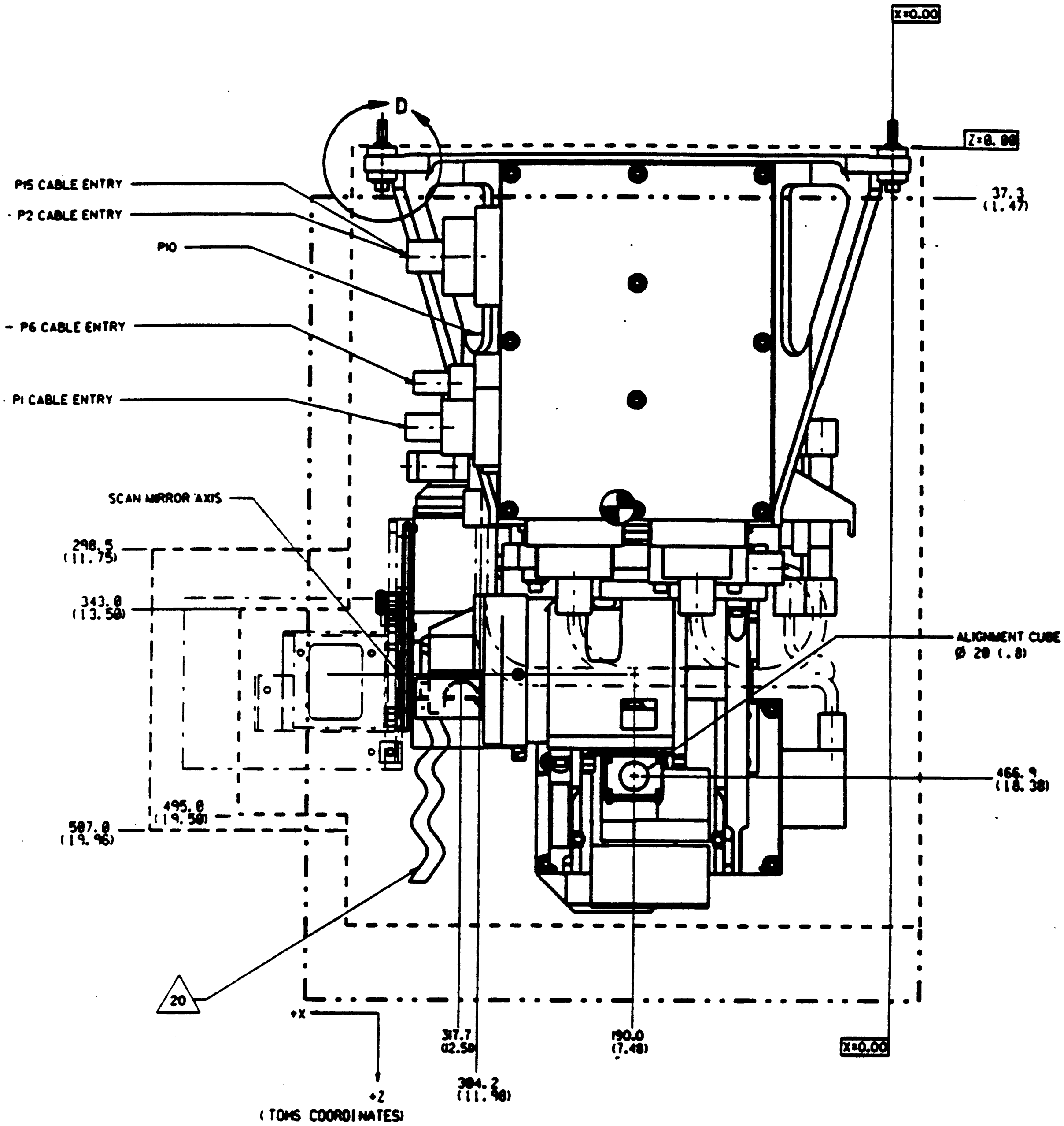

Figure 5B. TOMS Envelope and Mounting (Y-View; for reference only).

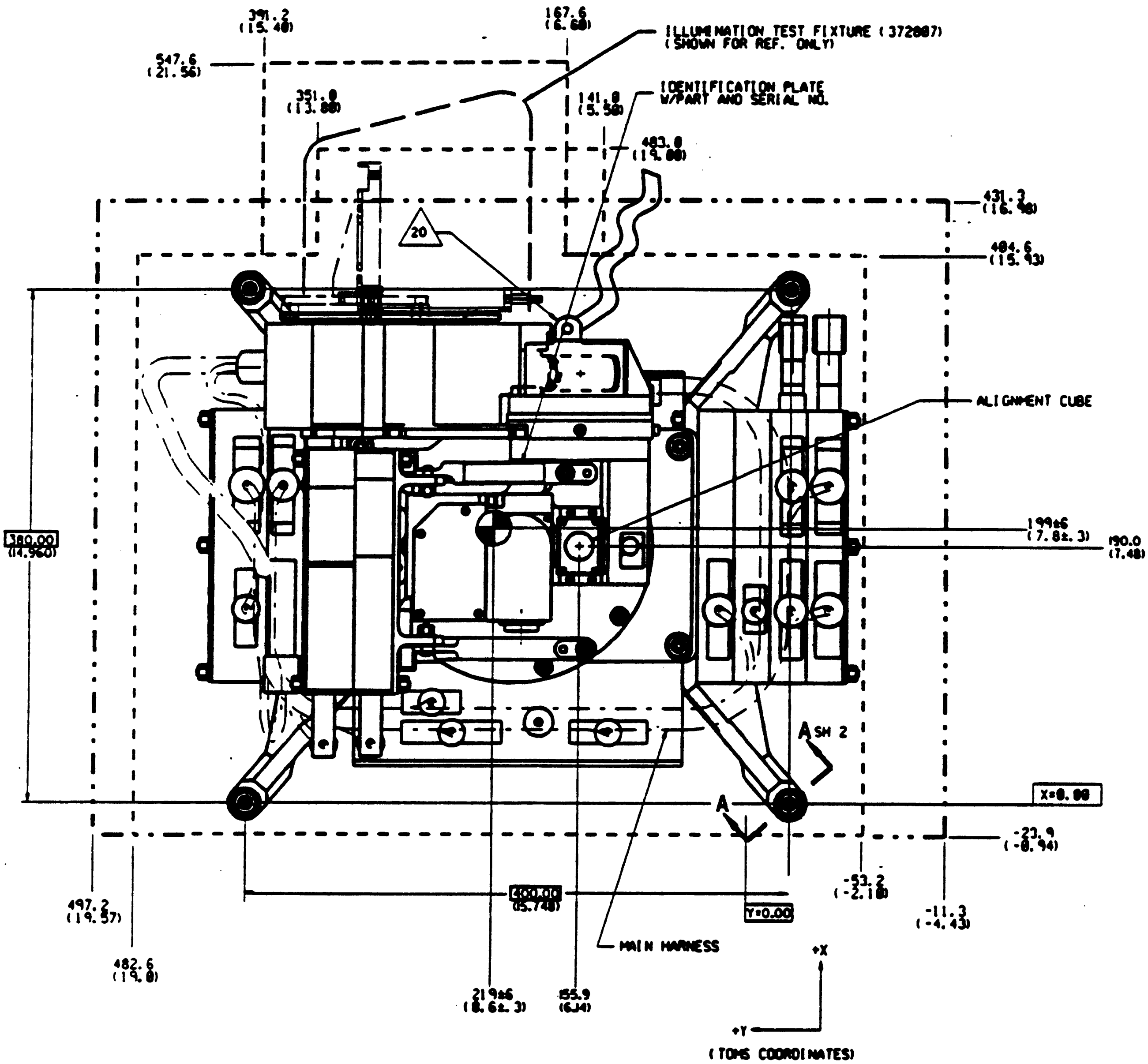

Figure 5C. TOMS Envelope and Mounting (Z-View; for reference only).

3.1.2.3.3 **Major Component Alignment.** Alignment between mechanical and optical components shall be as shown in Table 3. Azimuth and elevation are relative to XY plane.

Table 3. Major Component Alignment
I=Initial Tolerance or Knowledge, R=Repeatability or Stability

From	To	Align What	Tolerance	I/R	Units
Scanner	Align Mirror	Angles	±0.05	I	degrees
Scanner	Diffuser	Diff Azim	±0.15	R	degrees
Scanner	Diffuser	Scan Elev	±0.15	R	degrees
Scanner	Entr Optics	Elevation	±0.01	I	degrees
Scanner	Entr Optics	Azimuth	±0.01	I	degrees
Scanner	Entr Optics	X-Position	±0.5	I	mm
Scanner	Entr Optics	Z-Position	±0.5	I	mm
Entr Optics	Entr Slit	X-Position	±0.01	I&R	mm
Entr Optics	Entr Slit	Y-Position	±0.01	I&R	mm
Entr Optics	Entr Slit	Elevation	±0.03	I&R	degrees
Entr Optics	Entr Slit	Azimuth	±0.03	I&R	degree
Exit Slit	PMT Mask	X-Y Position	±0.05	I	mm
Exit Slit	PMT Mask	Z-Posn (Focus)	±0.2	I	mm
Chopper Disk	Slit Plate	X-Y Position	±0.025	I&R	mm
Chopper Disk	Slit Plate	Z-Position	±0.1	I&R	mm
Chopper Disk	PRP	Z-Position	±0.1	I&R	mm

3.1.2.4 **Thermal Interface.** The TOMS instrument shall have its own thermal control system. This system shall be designed to maintain temperature control of the TOMS when the temperature of the spacecraft surface to which it is mounted is between -10°C to +30°C when the TOMS is operating and between -30°C to +55°C when the TOMS is not operating. The instrument shall be designed to limit conductive heat transfer (through the mounting interface) to or from the spacecraft to less than 5W.

3.1.2.5 **Spacecraft Power Interface.** The spacecraft power and power interface shall be as specified in Table 3a. The power supply shall be designed for the worst case combination of unregulated bus voltage variation, noise and transients for any S/C TOMS is expected to operate. The TOMS low-voltage power supply shall supply all TOMS subsystems except for the survival and diffuser heaters.

3.1.2.6 **Command Interface.** The spacecraft command interface shall be as specified herein.

3.1.2.6.1 **Discrete Command Interface.** Discrete commands shall have the interface parameters specified in Table 3A, Discrete Command Interface Section Cross Reference, in accordance with NASDA-ESPC-01183.

Table 3a. Primary Power Interface Requirements.

Interface Description	Requirement
Normal Operating Input Voltage Range	+21 to +52 Vdc
Lower Abnormal Input Voltage	0 to +21 Vdc
Higher Abnormal Input Voltage	+52 to +53 Vdc
Source Impedance: Dc to +20 kHz 20 to -1 MHz	< 0.5 ohms + 6db/octave
Input Voltage Ripple Over the 0.1 Hz to 100 Mhz Range	< 1.0 V p-p
Load Current Rate of Change (excluding instrument turn-on transients)	$< 1 \times 10^5$ A/sec

Table 3A. Discrete Command Interface Section Cross Reference.

Command Interface Specifications	Parameters	NASDA-ESPC-01183 Section(s)
Discrete Commands	N/A	3.2.2.1.2
1. Input signal level	(load impedance 244Ω-5kΩ)	3.2.2.1.2(1)
Present (pulse exist)	26 ± 4 Vdc	
Maximum Current	90 mA	
Maximum Voltage	+32 Vdc	
Absent (no pulse)	0 ± 1.0 Vdc	
2. Pulse Length	30 ± 3 msec	3.2.2.1.2(2)
3. Output Circuit Type	(single end transistor)	3.2.2.1.2(3)
4. Command Return Line dc		3.2.2.1.2(4)
Isolation Resistance	> 1 MΩ	
5. Rise Time	≤ 10 μsec	3.2.2.1.2(5)
6. Fall Time	≤ 10 μsec	3.2.2.1.2(6)
7. TOMS Input Circuit	w/o back EMF	3.2.2.1.2(7)
8. Return Connection	one/4 signals	3.2.2.1.2(8)
9. Command Timing:		3.2.2.1.2(10)
Resolution	1 second	
Rate	1/second	
Variance	1.0 to +1.5 sec	

3.1.2.6.2 **Serial Command Interface.** Interfaces for serial commands shall have the interface parameters specified in Table 3B, Serial Command Interface Section Cross Reference, in accordance with NASDA-ESPC-01183.

3.1.2.6.3 **Command Relays.** Relays shall be provided to switch the instrument power and the survival and diffuser heater power on and off and to enable and disable the photomultiplier high voltage.

Table 3B. Serial Command Interface Section Cross Reference.

Command Interface Specifications	Parameters	NASDA-ESPC-01183 Section(s)
Serial Commands	N/A	3.2.2.2.3
1. Constitution	Enable, Gated Clock, Data	3.2.2.2.3(1)
2. Gated Clock:		3.2.2.2.3(2)
Clock Number	16	
Clock Rate	8.192 Khz (nominal)	
3. Data:		3.2.2.2.3(3)
Data Number	16 bit	
PCM Code	NRZ-L	
Bit Priority	MSB first	
4. Timing	(Figure 3.3.1.3.2-2)	3.2.2.2.3(4)
5. Output Circuit Type	(single end transistor)	3.2.2.2.3(5)
6. Output Voltage:	(load impedance: 10 ± 1 kΩ)	3.2.2.2.3(6)
"1"	+8 ~ 10.8 Vdc	
"0"	0 ± 1.0 Vdc	
7. Input Impedance in Two Parallel Load	10 ± 1 kΩ in parallel; (20 ± 2 kΩ each)	3.2.2.2.3(7)
8. Pulse Shape:	(10 ± 1 kΩ load impedance)	3.2.2.2.3(8)
Rise Time	≤ 10 μsec maximum	
Fall Time	≤ 10 μsec maximum	
9. Max Output Voltage	-1 Vdc; +15 Vdc	3.2.2.2.3(9)
10. TOMS Input Circuit:	N/A	3.2.2.2.3(10)
Each Signal	Provide redundant terminals	
Single Part Failure	Not degrade input function	
11. Enable Signal Time Internal	31.25 msec minimum	3.2.2.2.3(11)

3.1.2.7 **Mission Data Interface.** The spacecraft mission data interface shall be as specified herein.

3.1.2.7.1 **Bilevel Data Interface.** Bilevel telemetry shall have the interface parameters specified in Table 3C, Bilevel Data Interface Section Cross Reference, in accordance with NASDA-ESPC-01183. The internal interface for latching relay position confirmation shall be two lines per relay: normally open contact and contact arm (SPST).

3.1.2.7.2 **Passive Analog Telemetry Interface.** Passive analog telemetry shall have the interface parameters specified in Table 3D, Passive Analog Telemetry Interface Section Cross Reference, in accordance with NASDA-ESPC-01183. Seven 300Ω (at 25°C) thermistors shall be provided for temperature monitoring when TOMS is unpowered. The thermistor leads shall be brought out to the spacecraft interface with no signal processing.

Table 3C. Bilevel Data Interface Section Cross Reference.

Data Interface	Parameters	NASDA-ESPC-01183 Section(s)
Bilevel Telemetry Data: (passive)		3.2.3.2(2)
1. Input Circuit Type	Differential Balanced	3.2.3.2(2)(a)
2. Input Impedance	1 MΩ minimum/1 RIU	3.2.3.2(2)(b)
3. Signal Out Impedance:		
"1" Signal Source (contact open)	> 1 MΩ	3.2.3.2(2)(c)
"0" Signal Source (contact closed)	< 10 Ω	3.2.3.2(2)(c)
4. Impressed Voltage:		
To Signal Source	5 ±1.0 Vdc	3.2.3.2(2)(d)
Output Impedance	2.5 kΩ minimum	3.2.3.2(2)(e)
Time	(continuous)	3.2.3.2(2)(f)
5. Contact Capacity	30 mA minimum	3.2.3.2(2)(g)
6. Connector Pins:		
Signal	1 per signal	3.2.3.2(2)(h)
Return	1 per signal	3.2.3.2(2)(h)

Table 3D. Passive Analog Data Interface Section Cross Reference.

Data Interface	Parameters	NASDA-ESPC-01183 Section(s)
Passive Analog:		3.2.3.1(2)
1. Input Circuit Type	Differential balanced	3.2.1.1(2)(a)
2. Input Impedance	1 MΩ (minimum)	3.2.1.1(2)(b)
3. Driving Current for Thermistors	1.35 mA ± 2 % at	3.2.1.1(2)(d)
and Platinum Sensors	109 μsec (nominal)	3.2.1.1(2)(d)
4. Abs Output Voltage	-3 Vdc ~ +13 Vdc	3.2.1.1(2)(e)
5. Output Impedance	0.00 - 3.78 kΩ with	3.2.1.1(2)(f)
	40 pF maximum	3.2.1.1(2)(f)
6. A/D Conversion:		
Accuracy	±1 % (full scale)	3.2.1.1(2)(g)
Quantization	20 mV/1bit at	3.2.1.1(2)(g)
Conversion Time	20 μsec maximum	3.2.1.1(2)(g)
Quantization No.	8bit (MSB first)	3.2.1.1(2)(h)
7. Connector Pins:		
Signal 1/	1 per signal	3.2.1.1(2)(i)
Return 2/	1 per signal	3.2.1.1(2)(i)

1/ One signal corresponds to one return.

2/ The return terminals of output side shall be floating.

3.1.2.7.3 **Active Analog Telemetry Interface.** The active analog telemetry interface shall have the parameters as specified in Table 3E in accordance with NASDA-ESPC-01183. Only the input power shall be telemetered with a scale factor of 20 W/V.

Table 3E. Active Analog Data Interface Section Cross Reference.

Data Interface	Parameters	NASDA-ESPC-01183 Section(s)
1. Input Circuit Type	Differential Balanced	3.2.3.1(1)(a)
2. Input Impedance	1 MΩ minimum	3.2.3.1(1)(b)
3. Input Voltage	0.00 ~ +5.10 Vdc	3.2.3.1(1)(c)
4. Output Impedance	1 kΩ maximum 1/	3.2.3.1(1)(d)
5. A/D Conversion:		
Accuracy	±5% (full scale)	3.2.3.1(1)(e)
Quantization	20 Mv/bit	3.2.3.1(1)(e)
Conversion Time	20 μsec maximum	3.2.3.1(1)(e)
Quantization No.	8bit (MSB first)	3.2.3.1(1)(f)
6. Abs Max Input Voltage	±15 Vdc	3.2.3.1(1)(g)
7. Connector Pins:		
Signal 2/	1 per signal	3.2.1.1(1)(h)
Return 3/	1 per signal	3.2.1.1(1)(h)

1/ If the accuracy of item 5 is not required, then this output impedance can be up to 10KΩ max.
2/ One signal corresponds to one return.
3/ The return terminals of output side shall be floating.

3.1.2.7.4 **Mission Data Interface.** The TOMS output data rate shall be 736 bits per second. The serial mission data interface shall be as specified in Table 3F, in accordance with NASDA-ESPC-01183.

Table 3F. Mission Data Interface Section Cross Reference for FM-3.

Data Interface	Paramenters	IF3-0007 Section(s)
Mission Data Specifications	N/A	3.2.4.3
(1) Signals		
(a) From S/C	Data Gate, Data Clock	4.2.1.5
(b) From TOMS	Data	4.2.1.5
(2) Data Clock		
Clock Rate	8.192kHz±5%	4.2.1.5
(3) Data		
Digital Format	NRZ-L	4.2.1.5
Bit Priority	MSB First	4.2.1.5
(5) Enable		
Input Impedance	10KΩ	4.2.1.5
Rise/Fall Time	≤ 3 μsec	4.2.1.5
Duration (achive low)	0.97 msec	4.2.1.5
(d) Number of sampling bits	8 bits	4.2.1.5
(e) Sampling repetition rate	1.95 msec	4.2.1.5
(6) Logic Levels (AXP) "1"	+10V +1.0V/-1.5V	4.2.1.5
"0"	0V ± 1.0V	4.2.1.5
(7) Receiver Input Impedance	≥9.5kΩ	4.2.1.5
(8) Data Signal Rise/Fall Times	<25 μs	4.2.1.5
(9) Maximum output voltage from AXP or TOMS (Signal Failure)	-1V, +15V	4.2.1.5
(10) Circuit	See Figure 4.2.1-1b in IF3-0007	4.2.1.5
(11) Timing	See Figure 4.2.1.5-1 in IF3-0007	4.2.1.5

Table 3G. Mission Data Interface Section Cross Reference for FM-4.

Data Interface	Paramenters	NASDA-ESPC-01183 Section(s)
Mission Data Specifications	N/A	3.2.4.3
(1) Signals		
(a) From AXP	Data Gate, Data Clock	3.2.4.3(1)(a)
(b) From TOMS	Data	3.2.4.3(1)(b)
(2) Data Clock		
Clock Rate	8.192kHz±0.1%	3.2.4.3(2)
(3) Data		
Digital Format	NRZ-L	3.2.4.3(3)
(4) Frame Repetition Rate	8 sec ± 1 msec	3.2.4.3(4)
(5) Format		
(a) AXP's Major Frame Rate	8 sec ± 0.1%	3.2.4.3(5)(a)
(b) AXP's Minor Frame Rate	500 msec ± 0.1%	3.2.4.3(5)(b)
(c) Number of sampling per 1 AXP's Minor Frame	46	3.2.4.3(5)(c)
(d) Number of sampling bits	8 bits	3.2.4.3(5)(d)
(e) Sampling repetition rate	1.95 msec	3.2.4.3(5)(e)
(6) Logic Levels (AXP) "1"	+10V +1.0V/-1.5V	3.2.4.3(6)
"0"	0V ± 1.0V	
(7) Receiver Input Impedance	≥10kΩ (AXP output terminal)	3.2.4.3(7)
(8) Data Signal Rise/Fall Times	<25 μs	3.2.4.3(8)
(9) Maximum output voltage from AXP or TOMS (Signal Failure)	-1V, +15V	3.2.4.3(9)
(10) Circuit	See Figure 3.2.4-1 in NASDA-ESPC-01183	3.2.4.3(10)
(11) Timing	See Figure 3.2.4-2 in NASDA-ESPC-01183	3.2.4.3(11)
(12) Cable capacitance	≤950 pf	3.2.4.3(12)

3.1.2.8 **Time Sync Interface.** TOMS shall keep its own internal clock, independent of the spacecraft clock. The updating of the TOMS clock buffer shall be enabled at receipt of a minor frame rate signal from the spacecraft. The content of the clock buffer shall then be read and placed in the instrument's mission data at the receipt of an ascending node pulse. For TOMS FM-3, the minor frame and the ascending mode are one and the same signal. For TOMS FM-4 the minor frame signal and the ascneding mode signal are two separate signals. The specifications for the above signals are detailed in Tables 3H and 3I.

3.1.2.9 **Internal Electrical Interface.** To assure adaptability to different spacecraft, the TOMS instrument shall have standard internal controls and data interfaces. The electronic interfaces between components of the TOMS instrument and the spacecraft shall be as specified herein.

3.1.2.10 **Test Connectors.** Separate test connectors shall be provided for monitoring internal signals from the optics module and digital electronics. The connector locations and interfaces shall be as defined in the applicable Interface Control Drawings (371200 - 371500).

3.1.3 **Major Component List.** Table 4 lists the major systems and subsystems of the TOMS. The required performance characteristics shall be specified in the documents listed below (see 3.4, Major Component Characteristics, for controlling requirements).

3.2 **Characteristics.**

3.2.1 **Performance Characteristics.**

3.2.1.1 **Satellite Orbit Characteristics.** The TOMS shall operate within specification for satellite orbits with the ranges of characteristics listed in Table 5.

3.2.1.2 **Modes.** Primary modes shall be distinguished by having different data formats, operations or deployed components. A difference only in parameters shall not be considered to be a distinct mode.

3.2.1.2.1 **Primary Operational Modes.** The TOMS shall have the primary orbital operating modes listed below. Each mode shall have preset operating sequences and may have different output data content as specified herein. All steps to carry out each TOMS operating mode shall be stored within TOMS and shall be initiated in response to a command from the spacecraft.

Automatic control of the mechanisms and data sampling shall occur during primary operating modes. In addition, real time override functions shall be provided to turn on and turn off power to selected subsystems or reposition the various mechanisms.

Modes shall be entered according to a commanded mode sequence at the end of the current data-taking cycle (except for emergency overrides, if any). Commands may specify parameters. If no mode command is pending at the completion of the current mode, the TOMS shall go to Standby Mode.

Operations confirmed by sensor feedback (such as a reading of the scan encoder) shall have backup timing loops. Timeout durations shall be fixed parameters. Failure of any operation shall be flagged by error codes in the instrument status telemetry. Operations shall be sequential to avoid peak loads on the power supply.

Numeric codes (in hexadecimal) shall be used to indicate the current operating mode in the status record).

Table 3H. Time Sync Interface Section Cross Reference for FM-3

Minor Frame Interface Specification	Parameters	IF3-0007 Section(s)
1. Pulse duration	2.0 msec	4.2.1.3
2. Output voltage		
"1"	+8 to 10.8 Vdc	4.2.1.3
"0"	0 ± 1 Vdc	4.2.1.3
3. Rise/fall times	≤ 10 μsec	4.2.1.3
4. Max output voltage	-1 Vdc; +15 Vdc	4.2.1.3
Ascending Node Interface Specification	**Parameters**	**IF3-0007 Section(s)**
For TOMS FM-3 this signal is wired to the minor frame signal.		

Table 3I. Time Sync Interface Section Cross Reference for FM-4

Minor Frame Interface Specification	Parameters	NASDA-ESPC-01183 Section(s)
1. Pulse duration	2.0 msec	Figure 3.2.2-2
2. Output voltage		
"1"	+8 to 10.8 Vdc	3.2.2.2.3 (6)
"0"	0 ± 1 Vdc	
3. Rise/fall times	≤ 10 μsec	3.2.2.2.3 (8)
4. Max output voltage	-1 Vdc; +15 Vdc	3.2.2.2.3 (9)
Ascending Node Interface Specification	**Parameters**	**NASDA-ESPC-01183 Section(s)**
1. RIU output circuit type	Single ended	3.2.7.2 (1)
2. Pulse	29 ± 5μ sec	3.2.7.2 (2)
3. Output signal voltage		
"1"	+8.0V to +10.8V	3.2.7.2 (3)
"0"	0V ± 1V	
4. Output impedance		
"1"	1kΩ ± 20%	3.2.7.2 (4)
"0"	4kΩ ± 20%	
5. Load Impedance	9kΩ to 22Ω (10kΩ ± 10% at 2 parallel loads, where 20kΩ ± 10% each)	3.2.7.2 (5)
6. Pulse wave form		
Rise time	10μ sec or less	3.2.7.2 (6)
Fall time	10μ sec or less (for the above load impedance)	
7. Absolute maximum output voltage	-1V, +15V	3.2.7.2 (7)
8. Standard interface circuit	See Figure 3.2.7-1 in NASDA-ESPC-01183	3.2.7.2 (8)
9. Timing	See Figure 3.2.7-2 in NASDA- ESPC-01183	3.2.7.2 (9)

Table 4. TOMS Major Component Specifications

Specification Title (if separate)	Number
Scanner Subsystem	71-0153 (herein)
Motor, Stepper, 3°, Area Scanner	38-0701
Entrance Optics Subsystem (Optical Subsystem)*	65-0070
Diffuser Subsystem	71-0153 (herein)
Motor, Stepper, 3°, Diffuser Drive	38-0703
Stepping Motor Encoders	71-0187
Reflectance Calibration Subsystem	71-0153
Lamp Power Supplies	71-0186
Monochromator Subsystem (Optical Subsystem)*	65-0070
Chopper Subsystem	71-0153 (herein)
Motor, Three-Phase, Brushless, DC	38-0700
Encoder, Brushless DC Motor	65-0064
Chopper Servo Circuits	71-0185
Wavelength Monitor Subsystem (Optical Subsystem)*	65-0070
Lamp Power Supplies	71-0186
Photomultiplier Subsystem	71-0153 (herein)
Photomultiplier Tube Assembly	39-0366
High Voltage Power Supply	71-0182
Photomultiplier Tube Electrometer	71-0180
Voltage-to-Frequency Converter	71-0183
Electronic Calibration Subsystem	71-0184
Housekeeping Circuits	71-0188
Electronics Module (ELM) (Michigan)	71-0092
Low Voltage Power Supply (LVS)	71-0189
Motor and Heater Driver (MHD)	71-0092
Microprocessor (MP)	71-0092
Spacecraft/Optics Interface (I/O)	71-0092
TOMS Instrument Firmware	080086-460
Thermal Control System	71-0153 (herein)

*Refer to design note #30065-2400-02 revision A

Table 5. TOMS Orbital Parameter Range

Parameter	Minimum Altitude	Maximum Altitude	Units
Orbital Altitude	797±25	955±25	km
Orbital Period (nom)	100.4	104.3	min
Inclination (nom)	98.6	99.3	degrees
Earth Rotation per Orbit (nom)	25.11	26.08	degrees
Ground Speed (nom)	6.64	6.40	km/sec
Scan Width (IFOV center, nom)	108.0	102.0	degrees
Scan Width (IFOV center, nom)	37	35	3° positions
Sun-XZ Plane Angle (initial)	0 to 45	0 to 45	degrees
Sun-XZ Plane Angle (drift)	±7.5	±7.5	degrees

3.2.1.2.1.1 **Standby Mode.**

a. **Science Data Format.** Normal Format Science Data shall be sent in Standby Mode.

b. **Initial Hardware Configuration.** Before executing the operating sequence, the firmware shall set the hardware to the following state:

Scanner Position	Exposed Diffuser	Chopper Motor	ECAL	WRM Lamp	RCA Lamp
Stowed	Cover	On	Off	Off	Off

c. **Operating Sequence.**

1. Hold the scanner stationary.

2. If commanded into another mode, go to the commanded mode.

3.2.1.2.1.2 **Scan Mode.**

a. **Science Data Format.** Normal Format Science Data telemetry shall be sent in the Scan Mode.

b. **Initial Hardware Configuration.** Before executing the operating sequence, the firmware shall set the hardware to the following state:

Scanner Position	Exposed Diffuser	Chopper Motor	ECAL	WRM Lamp	RCA Lamp
First Scene	Cover	On	Off	Off	Off

c. **Operating Sequence.**

1. Step the scanner through each scene in the scan pattern measuring the radiance backscattered from the Earth. Format and telemeter the measurements.

2. If commanded into another mode, stow the scanner and go to the commanded mode.

3. Retrace back to the first scene in the scan pattern and go to Step 1.

3.2.1.2.1.3 **Solar Calibration Mode.**

a. **Science Data Format.** Normal Format Science Data telemetry shall be sent in Solar Calibration Mode.

b. **Initial Hardware Configuration.** Before executing the operating sequence, the firmware shall set the hardware to the following state:

Scanner Position	Exposed Diffuser	Chopper Motor	ECAL	WRM Lamp	RCA Lamp
Unchanged	Unchanged	On	Off	Off	Off

c. **Operating Sequence.** The SCAL duration shall be preselected by using the Set Parameter command. The diffuser and diffuser viewing percentage shall be selected via command data in the SCAL Mode command word.

1. Move the scanner to view the diffuser.

2. Expose the commanded diffuser.

3. Measure, format and telemeter radiance for one scan time.

4. If commanded into another mode, stow the scanner and diffuser and go to the commanded mode.

5. As required to maintain the commanded diffuser viewing percentage, move the scanner to view the RCA or diffuser.

6. Go to Step 3 until the selected number of SCAL scans are completed.

7. Stow the scanner and diffuser and go to Standby mode.

Note: In the process of exposing the commanded diffuser or exposing the cover diffuser, the remaining diffusers shall not be exposed, even momentarily.

3.2.1.2.1.4 **Wavelength Monitoring Mode.**

a. **Science Data Format.** Calibration Format Science Data telemetry shall be sent in Wavelength Monitoring Mode.

b. **Initial Hardware Configuration.** Before executing the operating sequence, the firmware shall set the hardware to the following state:

Scanner Position	Exposed Diffuser	Chopper Motor	ECAL	WRM Lamp	RCA Lamp
Stowed	Cover	On	Off	On	Off

c. **Operating Sequence.** The WMON duration shall be preselected by using the Set Parameter command.

1. Measure and telemeter the radiance at the 312.5 nm wavelength for one scan time (with the scanner held stationary).

2. If commanded into another mode, turn the WRM lamp off and go to the commanded mode.

3. Go to Step 1 until the selected number of WMON scans are completed.

4. Turn off the WRM lamp and go to Standby mode.

3.2.1.2.1.5 **Electronic Calibration Mode.**

a. **Science Data Format.** Calibration Science Data shall be sent in the Electronic Calibration Mode.

b. **Initial Hardware Configuration.** Before executing the operating sequence, the firmware shall set the hardware to the following state:

Scanner Position	Exposed Diffuser	Chopper Motor	ECAL	WRM Lamp	RCA Lamp
Stowed	Cover	On	On	Off	Off

c. **Operating Sequence.** The ECAL duration shall be preselected by using the Set Parameter command.

1. Set ECAL level to the minimum value.

2. Measure, format and telemeter the radiance measurements for one scan time (with the scanner held stationary).

3. If commanded into another mode, turn ECAL off and go to the commanded mode.

4. Advance the ECAL level to next higher level wrapping around to the lowest level if necessary.

5. Go to Step 2 until the selected number of ECAL scans are completed.

6. Turn off ECAL and go to Standby mode.

3.2.1.2.1.6 **Reflectance Calibration Mode.**

a. **Science Data Format.** Normal Science Data telemetry shall be sent in Reflectance Calibration Mode.

b. **Initial Hardware Configuration.** Before executing the operating sequence, the firmware shall set the hardware to the following state:

Scanner Position	Exposed Diffuser	Chopper Motor	ECAL	WRM Lamp	RCA Lamp
View Diffuser	Cover	On	Off	Off	On

c. **Operating Sequence.** The RCAL duration shall be preselected by using the Set Parameter command. The diffuser and diffuser viewing percentage shall be selected via command data in the RCAL Mode command word.

1. Wait until the RCA Lamp warms up to its temperature setpoint (with a 5 minute timeout).

2. Expose the commanded RCAL diffuser.

3. Measure, format and telemeter radiance for one scan time (with the scanner held stationary).

4. If commanded into another mode, turn the RCA lamp off, stow the scanner and diffuser and go to the commanded mode.

5. As required to maintain the commanded diffuser viewing percentage, move the scanner to view the RCA or diffuser.

6. Go to Step 3 until the selected number of RCAL scans are completed.

7. Turn the RCA lamp off, stow the scanner and diffuser and go to Standby mode.

Note: In the process of exposing the commanded diffuser or exposing the cover diffuser, the remaining diffusers shall not be exposed, even momentarily.

3.2.1.2.1.7 **Diagnostic Mode.**

a. **Science Data Format.** Diagnostic Science Data shall be sent in Diagnostic Mode.

b. **Initial Hardware Configuration.** Before executing the operating sequence, the firmware shall set the hardware to the following state:

Scanner Position	Exposed Diffuser	Chopper Motor	ECAL	WRM Lamp	RCA Lamp
First Scene	Cover	On	Off	Off	Off

c. **Operating Sequence.**

1. Step through the scan pattern measuring the radiance backscattered from the Earth.

2. Format and telemeter every 12th scan, sending light and dark readings for all ranges of all chops of the wavelengths.

3. If commanded into another mode, stow the scanner and go to the commanded mode.

4. Retrace back to the first scene in the scan pattern and go to Step 1.

3.2.1.2.1.8 **Microprocessor Test Mode.**

a. **Science Data Format.** Empty Science Data shall be sent in Microprocessor Test Mode.

b. **Initial Hardware Configuration.** The Microprocessor Test Mode shall not change the hardware configuration in any way.

c. **Operating Sequence.**

1. Verify the PROM cyclic redundancy code (CRC). If the stored CRC does not match the computed CRC, put an error code in the Error Queue.

2. If commanded into another mode, go to the commanded mode.

3. Wait until the start of the next scan time.

4. Verify the EEPROM CRCs. If the stored CRCs do not match the computed CRCs, put one or more error codes in the Error Queue.

5. If commanded into another mode, go to the commanded mode.

6. Wait until the start of the next scan time.

7. Test the RAM nondestructively for stuck bits (bits that cannot change value). If the RAM fails the test, put one or more error codes (maximum of 8) in the Error Queue.

8. Go to Direct Control Mode if executing RAM code or go to Unloaded Mode if executing PROM code.

3.2.1.2.1.9 **Dump Memory Mode.**

a. Science Data Format. Memory Dump Science Data shall be sent in Dump Memory Mode.

b. Initial Hardware Configuration. The Memory Dump Mode shall not change the hardware configuration in any way.

c. Operating Sequence.

1. Telemeter one packet of the commanded memory or I/O bytes in the Science Data section of the telemetry packet.

2. If commanded into another mode, go to the commanded mode.

3. Wait until the start of the next scan time.

4. Go to Step 1 until the commanded number of memory or I/O bytes have been telemetered.

5. Go to direct Control Mode if executing RAM code or go to Unloaded Mode if executing PROM code.

3.2.1.2.1.10 **Upload Memory Mode.**

a. Science Data Format. Empty Science Data shall be sent if executing PROM code. Normal Science Data shall be sent if executing EEPROM code.

b. Initial Hardware Configuration. The Upload Memory Mode shall not change the hardware configuration in any way.

c. Operating Sequence.

1. Wait for a command word.

2. If commanded into another mode, go to the commanded mode.

3. If the command word contains an upload byte, store the byte.

4. If additional upload bytes are expected, go to Step 1.

5. Go to Direct Control Mode if executing RAM code or Unloaded Mode if executing PROM code.

3.2.1.2.1.11 **Direct Control Mode.** While in the Direct Control Mode, TOMS motors and peripherals shall be controlled with the Direct Control commands. The Direct control Mode provides a means for externally commanded test, diagnostic and calibration sequences. In Direct Control Mode, the Science Data Format shall be selectable via Direct Control command.

a. Science Data Format. Upon entry to Direct Control Mode, the Science Data Format shall be set to Normal. While in Direct Control Mode, the Science Data Format shall be selectable using the Select Science Data Format command.

b. Initial Hardware Configuration. The hardware configuration shall be left as is.

c. Operating Sequence.

1. Wait for a command word.
2. If commanded into another mode, go to the commanded mode.
3. Execute the command.
4. Go to Step 1.

3.2.1.2.1.12 **Unloaded Mode.** The Unloaded Mode code shall be contained entirely in PROM. The Unloaded Mode shall be entered under the following two conditions:

1) Unconditionally upon cold start

2) Upon warm start if it is impossible to execute the code stored in EEPROM or the code contained in RAM.

There are two types of startup sequences: Warm Start and Cold Start. A Cold Start is caused by a Reset discrete command or a power interruption. A Warm Start is caused by a watchdog timer timeout and is used for SEU recovery. The Cold Start Sequence is shown in Figure 5D. The Warm Start Sequence is shown in Figure 5E.

a. Science Data Format. Empty Science Data shall be sent in the Unloaded Memory Mode.

b. Initial Hardware Configuration.

Scanner Position	Exposed Diffuser	Chopper Motor	ECAL	WRM Lamp	RCA Lamp
Stowed	Cover	Off	Off	Off	Off

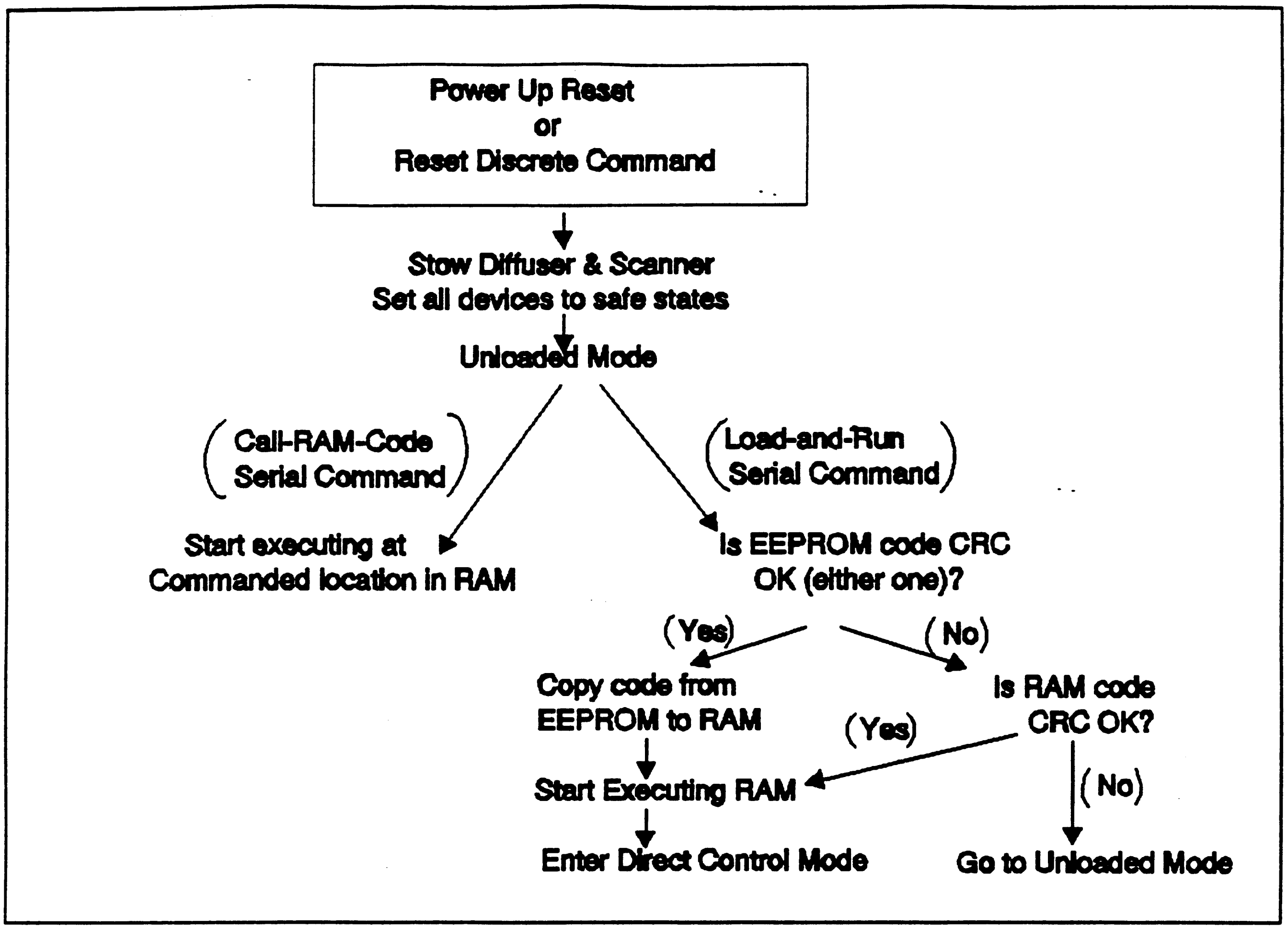

Figure 5D. Cold Start Sequence.

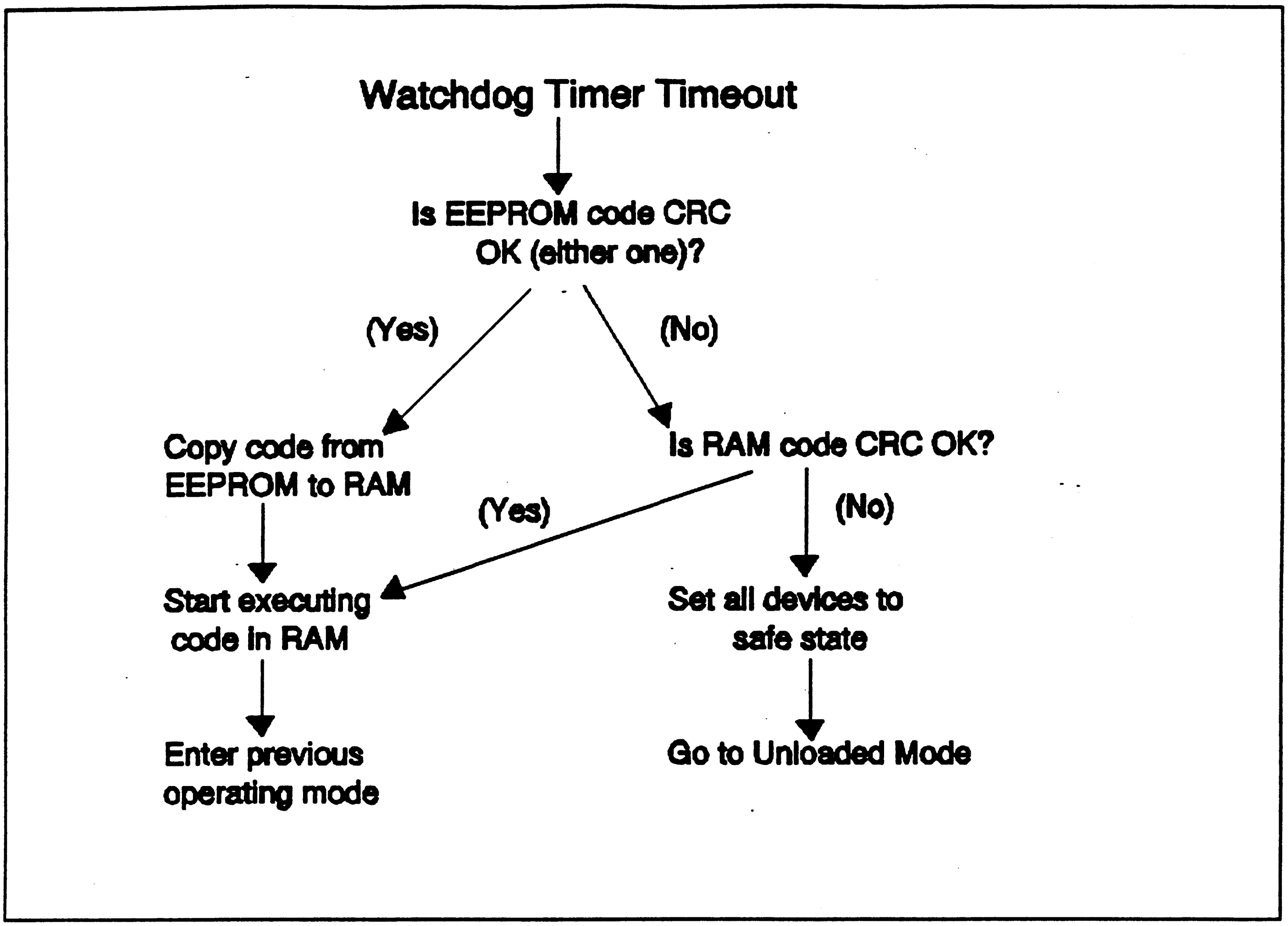

Figure 5E. Warm Start Sequence.

c. Operating Sequence.

1. Receive and process a limited set of serial commands including the following:

    a. Upload Memory Mode serial command.

    b. Download Memory Mode serial command.

    c. Microprocessor Test Mode serial command.

    d. Load-and-Run serial command.

    e. Call-RAM-Code serial command.

    f. No-Operation serial command.

3.2.1.2.2 **Launch Mode.** During launch, the TOMS instrument shall be powered off with the scanner and diffusers placed in the protected stow positions. The TOMS diffuser heater power shall be on during launch.

3.2.1.3 **Instrument Parameters.** The parameters listed in Table 6 shall either be adjustable before launch (in ROM) or shall be commandable in flight, as shown. The parameters shall be echoed back continuously in a digital subcom (see Table 10).

3.2.1.4 **Command Functions.** Commands shall be transmitted in the formats specified herein. The commands supported shall be as follows:

3.2.1.4.1 **Relays.** Relays shall be provided for the following discrete command functions. Redundant relays shall be provided as specified herein, and consist of two latching relays connected in three-way switch mode (exclusive-or):

3.2.1.4.1.1 **Power On & Off.** Spacecraft power shall be switched on and off by redundant latching relays located in the power subsystem (two discrete commands required for each relay, on & off).

3.2.1.4.1.2 **Survival Heater On & Off.** Survival heater power shall be switched on and off by redundant latching relays located in the power subsystem (two discrete commands required for each relay, on & off). Power shall be drawn from the unregulated bus. Heaters shall be electrically isolated from the housing and from power and signal ground. Contact rating shall be 2 A.

3.2.1.4.1.3 **Diffuser Heater On & Off.** Diffuser heater power shall be switched on and off by redundant latching relays located in the power subsystem (two discrete commands required for each relay, on & off). Power shall be drawn from the unregulated bus. Heaters shall be electrically isolated from the housing and from power and signal ground. Contact rating shall be 2 A.

3.2.1.4.1.4 **Memory Select Primary/Secondary.** The active read-only memory bank shall be selected by a latching relay located in the power subsystem (two discrete commands required, on & off). This selection shall override all other memory selection circuitry. The active bank shall be identified in the bilevel telemetry. Contact rating shall be 2 A.

3.2.1.4.1.5 **High Voltage Enable/Disable.** A latching relay located in the power subsystem (two discrete commands required, on & off) shall be used to enable or disable the high voltage supply by breaking the power connection Contact rating shall be 2 A.

3.2.1.4.1.6 **Emergency Off.** The TOMS shall enter the Standby Mode when this discrete command is received. One discrete command shall be required. A delay of not less than 10 seconds shall be provided for stowing the scanner and diffuser before spacecraft power is turned off.

3.2.1.4.1.7 **Reboot Microprocessor.** This command shall cause an immediate processor reset . The processor shall then execute the Warm Start Mode sequence.

Table 6. Instrument Parameters

Parameter	Para ID	Parameter Range	Units/Notes
Chopper Speed	00H	15 to 20	10 msec/revolution
Scenes per Scan	01H	35 or 37	
Scan Direction	02H	0 or 1	0 = -Y to +Y 1 = +Y to -Y
PMT Demodulator Phase	03H	-500 to 500	VFC clocks
ECAL clock phase(1)	04H	-500 to 500	VFC clocks
High Voltage Adjust	05H	0 to 255	0 = -800V 255 = -2000V (4.96 V / Step
SCAL duration	06H	0 to 65,535	scans
WMON duration	07H	0 to 65,535	scans
ECAL duration	08H	0 to 65,535	scans
RCAL duration	09H	0 to 65,535	scans
PMT Heater Setpoint	0AH	0 to 4095	thermistor counts
PMT Heater Proportional Band	0BH	0 to 4095	thermistor counts
PMT Heater Integral Coefficient	0CH	0 to 32767	0 = coef. of 0.0 32767 = coef. of 1.0
Lower Housing Heater Setpoint	0DH	0 to 4095	thermistor counts
Lower Housing Heater Proportional Band	0EH	0 to 4095	thermistor counts
Lower Housing Integral Coefficient	0FH	0 to 32767	0 = coef. of 0.0 32767 = coef. of 1.0
RCA Lamp Heater Setpoint (Lamp OFF)	10H	0 to 4095	thermistor counts
RCA Lamp Heater Proportional Band (Lamp OFF)	11H	0 to 4095	thermistor counts
RCA Lamp Heater Integral Coefficient (Lamp OFF)	12H	0 to 32767	0 = coef. of 0.0 32767 = coef. of 1.0
RCA Lamp Heater Setpoint (Lamp ON)	13H	0 to 4095	thermistor counts
RCA Lamp Heater Proportional Band (Lamp ON)	14H	0 to 4095	thermistor counts
RCA Lamp Heater Integral Coefficient (Lamp ON)	15H	0 to 32767	0 = coef. of 0.0 32767 = coef. of 1.0

(1) The ECAL clock phase value is dependent on the PMT demodulator phase value and should be adjusted once the PMT demodulator value has been set.

3.2.1.4.1.8 **Spare.** This discrete command relay shall be provided as a spare.

3.2.1.4.2 **(Not Used)**

3.2.1.4.3 **Serial Commands.** Serial commands shall be as follows.

3.2.1.4.3.1 **Time Sync.** The minor frame pulse and the Ascending Node pulse shall be used to latch the internal elapsed-time orbit clock. The value shall be telemetered in the parameter subcom. The time sync period for the minor frame pulse shall be in the range of 0.5 to 150 minutes.

3.2.1.4.3.2 **Serial Magnitude Commands.** Serial magnitude commands, both mode and direct control commands) and their parameters shall be those listed in Tables 7A and 7B. Word length shall be 16 bits, transmitted MSB first. The leading (MS) bit shall be 1 for the command itself (Word 1), and 0 for following parameter words, if any (Words 2..N). The next seven bits of Word 1 shall be the command identifier (ID Code). The last eight bits (0-7) of Word 1 may include parameters. All unused bits shall be set to zero.

3.2.1.5 **Output Data.** The TOMS may transmit data to a spacecraft interface subsystem. All data packets shall be flagged with the orbit clock. The interface subsystem may edit and format only the data required and used by the spacecraft.

3.2.1.5.1 **Orbit Clock.** The orbit time count shall be maintained in a 32-bit binary counter clocked at 50 Hz. Stability of the clock shall be less than or equal to 7.5ppm over the temperature range of -10°C to 40°C. The clock shall be recorded by Time Sync signals.

3.2.1.5.2 **Bilevel Telemetry Data.** Relay contact closures shall provide confirmation of latching relay status.

Table 7A. Serial Magnitude Mode Commands
See Table 6 For Parameter Definitions
Parameter Values in Bits 0-7 of Word 1 Unless Otherwise Noted

ID Code	Mnemonic	Function	Parameter(s)
00H	STBY	Standby Mode	None
01H	SCAN	Scan Mode	None
02H	SCAL	Solar Calibration Mode	Byte 0 Bits 0-3: Exposed Diffuser: 0H = Cover 1H = Working 2H = Reference Byte 0 Bits 4-7: Diffuser Viewing Percentage: 0H = 0% 1H = 6.7% 2H = 13.3% ... FH = 100%
03H	WMON	Wavelength Monitoring Mode	None
04H	ECAL	Electronic Calibration Mode	None
05H	RCAL	Reflectance Calibration Mode	Byte 0 Bits 0-3: Exposed Diffuser: 0H = Cover 1H = Working 2H = Reference Byte 0 Bits 4-7: Diffuser Viewing Percentage: 0H = 0% 1H = 6.7% 2H = 13.3% ... FH = 100%
06H	DM	Diagnostic Mode	None
07H	MTST	Microprocessor Test Mode	None
08H	DNLDM	Dump Memory Mode	Byte 0: Dump Address MSB Byte 1: Dump Address LSB Byte 2: Dump Segment: 00H = RAM 02H = EEPROM 04H = I/O 06H = MP Deck I/O 0FH = PROM Byte 3: Dump Length MSB Byte 4: Dump Length LSB

Table 7A. Serial Magnitude Mode Commands
See Table 6 For Parameter Definitions
Parameter Values in Bits 0-7 of Word 1 Unless Otherwise Noted

ID Code	Mnemonic	Function	Parameter(s)
09H	UPLDM	Upload Memory Mode	Byte 0: Start Address MSB Byte 1: Start Address LSB Byte 2: Upload Segment: 00H = RAM 02H = EEPROM 06H = I/O Byte 3: # of Bytes to Upload MSB Byte 4: # of Bytes to Upload LSB Byte 5 to N: Upload Data Bytes
0AH	DC	Direct Control Mode	None

Table 7B. Serial Magnitude Direct Control Commands
See Table 6 For Parameter Definitions
Parameter Values in Bits 0-7 of Word 1 Unless Otherwise Noted

ID Code	Mnemonic	Function	Parameter(s)
30H	PS_DC	Position Scanner	Byte 0: Scanner Position Code -60 to 59 (C4H to 3BH) 1/
31H	PD_DC	Position Diffuser	Byte 0: Diffuser Position Code -60 to 59 (C4H to 3BH) 0 = cover diffuser +40 = working diffuser -40 = ref. diffuser 1/
32H	RLMP_-DC	RCA Lamp Off/On	Byte 0: 00H = off, 01H = on
33H	WLMP_-DC	WRM Lamp On/Off	Byte 0: 00H = off, 01H = on
34H	HV_DC	High Voltage On/Off 2/	Byte 0: 00H = off, 01H = on
35H	CHPR_DC	Chopper Motor On/Off	Byte 0: 00H = off, 01H = on
36H	ECAL_DC	ECAL On/Off and Level	Byte 0: 00H to 08H = ECAL Level 00H = off 01H = ECAL on 0.0 mV 02H = ECAL on 8mV 03H = ECAL on 26.7mV 04H = ECAL on 80mV 05H = ECAL on 267mV 06H = ECAL on 800mV 07H = ECAL on 2.67V 08H = ECAL on 8V
37H	DATA_DC	Select Science Data Format	Byte 0: 00H = Normal 01H = Calibration 02H = (Unused) 03H = Diagnostic Pkt 1 04H = Diagnostic Pkt 2 ... 0EH = Diagnostic Pkt 12 0FH = Empty Science

1/ See Table 12 for scan encoder code.

2/ The High Voltage Enable/Disable relay together with the High Voltage On/Off serial command shall provide interlocking control of the high voltage power supply as follows:

a. The firmware shall turn the high voltage OFF if:
   1) The HV Enable/Disable relay is set to the disabled position OR
   2) The HV Off serial command is received.

b. The firmware shall turn the high voltage ON only if:
   1) The HV Enable/Disable relay is set to the enabled position AND
   2) The HV On serial command is received.

3.2.1.5.3 **Serial Data.** Output serial data shall be transmitted in bit-serial format in data packets of fixed length, called TOMS Telemetry Packets (TTP). Each logical packet shall contain data for an integral number of wavelength scan (chopper) cycles. Each packet shall contain a sync code, subcommutated analog housekeeping data, instrument status, and mode-dependent science data. The packet format shall be as shown in Table 8.

Table 8. TOMS Telemetry Packet Format

Date Item	Bit Position	No. of Bits
Sync Code	0	32
Analog Data	32	56
Instrument Status Record (Tables 10 - 13)	88	216
Time Stamp (Table 14)	304	72
Mode-Dependent Science Data (Tables 15 - 20)	376	3704

3.2.1.5.3.1 **Sync Code.** The 32-bit sync code shall be EACB8AD8H for the first pocket after each cold start or warm start; the sync code pattern shall be inverted in every other packet.

Table 8A. TOMS Sync Code Format.

Field Description	Bit Position	No. of Bits
Frame Sync Code Byte 0 = EAH	0	8
Frame Sync Code Byte 1 = CBH	8	8
Frame Sync Code Byte 2 = 8AH	16	8
Frame Sync Code Byte 3 = D8H	24	8

3.2.1.5.3.2 **Analog Data.** The analog data section shall contain the values listed in Table 9A at the respective bit positions relative to the beginning of the analog data section. Each data item listed in Table 9B shall be subcommutated and transmitted at the rate of four items per packet. Analog data within a packet shall be unambiguously identified by an ID code, by position, or both, as necessary.

Table 9A. TOMS Analog Data Format.

Field Description	Bit Position	No. of Bits
Subcom Analog Monitor 0	0	12
Subcom Analog Monitor 0	12	12
Subcom Analog Monitor 0	24	12
Subcom Analog Monitor 0	36	12
Analog Monitor Group ID (0 - 7)	48	3
Spare	51	1
Analog Data Checksum (covers bits 0 - 51)	52	4

3.2.1.5.3.3 **Instrument Status.** The instrument status record fields shall be as shown in Table 10a. The data validity flag shall be false (Logic 0) for the entire packet if commanded timeouts are not complete, the chopper or wavelength scanner drops out of sync, or the scanner, diffuser, calibration, or any other subsystem does not go in commanded state within the specified timeout period. Instrument parameter data shall be confirmed by a digital subcom. The nadir radiance data shall consist of all three photomultiplier electrometer output readings, including the range telemetered in the science data format for the nadir scene. The two most significant bits shall identify the range. Serial magnitude command codes shall be as listed in Table 7. The operating mode field shall indicate the current operating mode. The operating mode field values shall be interpreted as indicated in Table 10B. The science data format field shall indicate the current telemetry science data format. The science data format field values shall be interpreted as indicated in Table 10C. Minimum error codes shall be those listed in Table 11. The scanner and diffuser position codes shall be as shown in Table 12 and 13 respectively. The chopper phase error indicator shall have a resolution of 0.003 degrees.

Table 9B. Analog Data Subcommutated Groups.
12 data bits per word, 4 words and 3 ID bits per packet
(multiplexer references are thermistor bias voltage)

Signal ID	Group ID	Data Item	Symbol	Range	Scale Factor
0	0	Multiplexer #1 Zero Reference	MUX1	0-0.1V	N/A
1	0	Multiplexer #1 Reference Voltage	TBV1	2.194-2.258V	0.466 V/V
2	0	Low Voltage Power Supply Temperature	PST	0-5V	Note 1
3	0	PMT Housing Temperature	PMT	0-5V	Note 1
4	1	Spare Temperature Monitor	SPR4	N/A	N/A
5	1	Diffuser Housing Temperature	DHT	0-5V	Note 1
6	1	WRM Lamp Temperature	WMT	0-5V	Note 1
7	1	RCA Lamp Temperature	RLT	0-5V	Note 1
8	2	Plus Y, Monochromator Flange Temp.	PYMFT	0-5V	Note 1
9	2	Plus Y, Monochromator Housing Temp.	PYMHT	0-5V	Note 1
10	2	Minus Y, Monochromator Housing Temp.	MYMHT	0-5V	Note 1
11	2	Minus Y, Monochromator Flange Temp.	MYMFT	0-5V	Note 1
12	3	Plus Y Radiator Temperature	PYRT	0-5V	Note 1
13	3	Minus Y Radiator Temperature	MYRT	0-5V	Note 1
14	3	Lower Housing Radiator Temperature	LHRT	0-5V	Note 1
15	3	Spare Temperature Monitor	SPR15	N/A	N/A
16	4	Multiplexer #2 Zero Reference	MUX2	0-0.1V	N/A
17	4	Multiplexer #2 Reference Voltage	TBV2	2.194-2.258V	0.466 V/V
18	4	OPM Logic Voltage	LV	2.4-2.6V	0.5 V/V
19	4	PMT High Voltage Monitor	HV	1.6-4V	0.002 V/V
20	5	Chopper Motor Voltage	CMV	0-5V	0.2 V/V
21	5	Chopper Motor Current	CMI	0-5V	0.1 V/mA
22	5	PRP Photodiode Bias	PRPB	0-5V	0.4 V/V
23	5	LVPS Monitor (while not stepping)	PSMON1	0-5V	20 W/V
24	6	H.V. Power Supply Temperature	HVT	0-5V	Note 1
25	6	Lower Housing Flange Temperature	LHFT	0-5V	Note 1
26	6	Diffuser Motor Temperature	DMT	0-5V	Note 1
27	6	Spare Analog Monitor	SPR27	N/A	N/A
28	7	Spare Analog Monitor	SPR28	N/A	N/A
29	7	LVPS Monitor while scanner is stepping 2/3/	PSMON2	0-5V	20 W/V
30	7	Reserved 2/	N/A	0-0.1V	N/A
31	7	Reserved 2/	N/A	0-0.1V	N/A

1/ Use the thermistor R vs T curve with a load of 37.4K ±0.1%.
2/ These multiplexer inputs are grounded on the corresponding Circuit Card Assembly.
3/ The 12 bits allocated for serial data transmission of this input shall be utilized by the second sample of the LVPS monitor signal which is acquired during scanner motor retrace.

Table 10A. Instrument Status Record.			
Field Description	**Abbrev**	**Bit Position**	**No. of Bits**
Operating Mode	OM	0	4
Science Data format (0-7)	SDF	4	4
Error Code (Microprocessor Error)	MPE	8	8
Last Magnitude Command Processed	LC	16	16
Parameter Subcom Data	PSCD	32	16
Parameter Subcom ID	PSID	48	6
Chopper Motor On/Off	CH	54	1
High Voltage On/Off	HV	55	1
Scan Motor Encoder Readback	SMENC	56	6
Minimal Telemetry Flag	MFT	62	1
Spare	SPARE	63	1
Diffuser Motor Encoder Readback	DP	64	3
Spares	SPARE	67	5
RCA Lamp On/Off	RCA	72	1
WRM Lamp On/Off	WRM	73	1
More Than 4 Errors Queued	MT4E	74	1
More Than 16 errors Queued	MT16E	75	1
Spares	SPARE	76	3
Primary PROM Selected	PROMSEL	79	1
Chopper Servo Outer Loop Error	OLE	80	8
ECAL Level	ECAL	88	4
Chopper Servo Inner Sync Loop Error Flag	ILF	92	1
Chopper Servo Inner Sync Loop Error Sign	ILS	93	1
High Voltage Enabled/Disabled	HVEN	94	1
Science Data Valid	SDVLD	95	1
Nadir Scene Radiance Range (Always 1)	NSIRNG1	96	2
Nadir Scene Radiance #1	NS1	98	14
Nadir Scene Radiance Range (Always 2)	NS2RNG2	112	2
Nadir Scene Radiance #2	NS2	114	14
Nadir Scene Radiance Range (Always 3)	N53RNG3	128	2
Nadir Scene Radiance #3	NS3	130	14
PMT Heater Duty Cycle	PMTHDC	144	8
Lower Housing Heater Duty Cycle	LHHDC	152	8
RCA Lamp Heater Duty Cycle	RLHDC	160	8
Spare Bytes 0 to 4	SPARE	168	40
Instrument Status Checksum	SCK	208	8

Table 10B. Operating Mode	
Code	**Mode**
0H	Standby Mode
1H	Scan Mode
2H	Solar Calibration Mode
3H	Wavelength Monitoring Mode
4H	Electronic Calibration Mode
5H	Reflectance Calibration Mode
6H	Diagnostic Mode
7H	Microprocessor Test Mode
8H	Dump Memory Mode
9H	Upload Memory Mode
AH	Direct Control Mode
BH	Spare
CH	Spare
DH	Spare
EH	Unloaded Mode
FH	Mode Change in Progress

Table 10C. Science Data Format	
Code	**Format**
0H	Normal Science Data Format
1H	Calibration Science Data Format
2H	Memory Dump science data Format
3H	Diagnostic Science Data Format - Packet 1
4H	Diagnostic Science Data Format - Packet 2
5H	Diagnostic Science Data Format - Packet 3
6H	Diagnostic Science Data Format - Packet 4
7H	Diagnostic Science Data Format - Packet 5
8H	Diagnostic Science Data Format - Packet 6
9H	Diagnostic Science Data Format - Packet 7
AH	Diagnostic Science Data Format - Packet 8
BH	Diagnostic Science Data Format - Packet 9
CH	Diagnostic Science Data Format - Packet 10
DH	Diagnostic Science Data Format - Packet 11
EH	Diagnostic Science Data Format - Packet 12
FH	Empty Science Data (all zeros)

Table 11. Error Codes F=Fatal; N=Non-Fatal; Codes in Hex 1/		
Code	**Error**	**F/N**
00H	No Error	---
01H	Command Error - Unknown command ID	N
02H	Command Error - First Word flag in wrong state	N
03H	Command Error - Command data out of range	N
04H	Command Error - Direct control command not valid in this mode	N
05H	Command Error - Wrong number of command words	N
06H	Command Error - Wrong command ID	N
10H	Telemetry Register Underflow	N
11H	Command Register Overflow	N
12H	Command Queue Overflow	N
20H	Cold Start - CPU was cold started since the previous packet was telemetered	F
21H	Warm Start - CPU was warm started since the previous packet was telemetered	N
22H	RAM data bit stuck at 0 or 1	N
23H	Uploaded byte did not verify when read back from memory	N
24H	EEPROM data segment size CRC failed	N
25H	EEPROM executable code CRC failed	N
26H	EEPROM parameters CRC failed	N
27H	EEPROM backup data segment size CRC failed	N
28H	EEPROM backup executable code CRC failed	N
29H	EEPROM backup parameters CRC failed	N
2AH	PROM failed CRC Test	N
2BH	EEPROM parameter update failed	N
40H	Scanner Response Error - Unexpected encoder position readback.	N
41H	Diffuser Response Error - Unexpected encoder position readback	N
42H	The Position Scanner command was interrupted by a mode change command before the scanner was in the correct position.	N
43H	The Position Diffuser command was interrupted by a mode change command before the diffuser was in the correct position.	N
44H	HV Disabled Error - The high voltage could not be turned on because the High Voltage Enable relay is in the disable position.	N
Code	**Error**	**F/N**

Table 11. Error Codes F=Fatal; N=Non-Fatal; Codes in Hex 1/		
Code	**Error**	**F/N**
70H	Previous warm start was due to: Not definitely known - Watchdog timed out for some unknown reason.	N
71H	Previous warm start was due to: Scanner motor position error.	N
72H	Previous warm start was due to: Diffuser motor position error.	N
73H	Previous warm start was due to: RAM parity error.	N
74H	Previous warm start was due to: INT 3 interrupt. Indicates that the CPU attempted to execute code from an area of RAM that contains no executable code.	N
75H	Previous warm start was due to: Unexpected interrupt.	N
76H	Previous warm start was due to: 8086 single step interrupt.	N
77H	Previous warm start was due to: 8086 interrupt on overflow interrupt.	N
78H	Previous warm start was due to: Timer 1 interrupt.	N
79H	Previous warm start was due to: Command register overflow interrupt.	N
7AH	Previous warm start was due to: Telemeter register underflow interrupt.	N
7BH	Previous warm start was due to: Slave PIC spurious interrupt.	N
7CH	Previous warm start was due to: Timer 3 interrupt.	N
7DH	Previous warm start was due to: Master PIC spurious interrupt.	N
7EH	Previous warm start was due to: PROM Load and Run command.	N
7FH	Previous warm start was due to: Warm start command.	N
80H	Previous warm start was due to: Failed to complete a scan within the expected time.	N
F0H	Illegal Interrupt	F

1/ Fatal cause a restart

Table 12. Scan Encoder Definition 0=Opaque (Buffer Output High), 1=Transparent (Buffer Output Low) Angular intervals = Sector Angle ±1.5° unless otherwise specified			
Sector Angle, Degrees (+Y=+90°)	**Notes**	**Scan Code ABCDEF**	**Scan Code Octal, Low True**
±180	Stow	110110	66
-118.5 to -178.5	Sector 3 Left	110010	62
-117	RCAL Left #2	110011	63
-114	RCAL Left #1	110001	61
-91.5 to -112.5	Sector 2 Left	111001	71
-90	Calibrate Left	111011	73
-55.5 to -88.5	Sector 1 Left	111010	72
-54	Position 18 Left	111110	76
-51	Position 17 Left	111111	77
-48	Position 16 Left	111101	75
-45	Position 15 Left	111100	74
-42	Position 14 Left	101100	54
-39	Position 13 Left	101101	55
-36	Position 12 Left	101111	57
-33	Position 11 Left	101110	56
-30	Position 10 Left	101010	52
-27	Position 9 Left	101011	53
-24	Position 8 Left	101001	51
-21	Position 7 Left	100001	41
-18	Position 6 Left	100011	43
-15	Position 5 Left	100010	42
-12	Position 4 Left	100110	46
-9	Position 3 Left	100111	47
-6	Position 2 Left	100101	45
-3	Position 1 Left	100100	44

*Negative angles shall correspond to scanning toward the TOMS - Y axis.

Table 12, Scan Encoder Definition (Continued). 0=Opaque (Buffer Output High), 1=Transparent (Buffer Output Low)			
Sector Center Angle, Degrees (Nadie = 0)	**Notes**	**Scan Code ABCDEF**	**Scan Code Octal, Low True**
0	Nadir	000000	00
3	Position 1 Right	001001	11
6	Position 2 Right	001011	13
9	Position 3 Right	001010	12
12	Position 4 Right	001110	16
15	Position 5 Right	001111	17
18	Position 6 Right	001101	15
21	Position 7 Right	001100	14
24	Position 8 Right	011100	34
27	Position 9 Right	011101	35
30	Position 10 Right	011111	37
33	Position 11 Right	011110	36
36	Position 12 Right	011010	32
39	Position 13 Right	011011	33
42	Position 14 Right	011001	31
45	Position 15 Right	010001	21
48	Position 16 Right	010011	23
51	Position 17 Right	010010	22
54	Position 18 Right	010110	26
55.5 to 88.5	Sector 1 Right	010111	27
90	Calibrate Right	010101	25
91.5 to 112.5	Sector 2 Right	010100	24
114	RCAL Right #1	110100	64
117	RCAL Right #2	110101	65
118.5 to 178.5	Sector 3 Right	110111	67

Table 13. Diffuser Encoder Definition 0=Opaque (High), 1=Transparent (Low)			
Carousel Position, Degrees	**Exposed Diffuser**	**Code ABC**	**Code Octal, Low True**
0	Cover (Stow)	101	5
120	Working	011	3
240	Reference	110	6
Any other	N/A	000	0

3.2.1.5.3.4 **Time Stamp.** The time stamp format shall be as shown in Table 14.

Table 14. Time Stamp Record. Data per TOMS Telemetry Packet		
Data Item	**Bit Position**	**No. of Bits**
TOMS Clock Time	0	32
Spacecraft Sync Time	32	32
Time Sync Checksum	64	8

3.2.1.5.3.5 **Science Data Structure.** All science data formats shall use a common structure that defines a fixed location for data records and data record checksums. The science data common structure shall be as defined in Table 15. The bit positions in Table 15 are relative to the beginning of the science data section.

Table 15. Science Data Structure. Data per TOMS Telemetry Packet		
Data Item	**Bit Position**	**No. of Bits**
Scene 0 Data Record	0	96
Scene 1 Data Record	96	96
Scene 0 Data Record Checksum	192	4
Scene 1 Data Record Checksum	196	4
Scene 2 Data Record	200	96
Scene 3 Data Record	296	96
Scene 2 Data Record Checksum	392	4
Scene 3 Data Record Checksum	396	4
(Scene 4-35 Data Records and Checksums)	400	3200
Scene 36 Data Record	3600	96
Scene 36 Data Record Checksum	3696	4
Unused	3700	4

3.2.1.5.3.5.1 **Data Record Checksum.** The checksum shall be the 4-bit arithmetic sum, with carries ignored, of all the nibbles(4-bit groupings) in the data record.

3.2.1.5.3.5.2 **Radiance Data.** During each rotation of the chopper data shall be gathered for each band in two chops. Each chop shall consist of a light signal, U, preceded and followed by one dark period, D1, D2, as shown in Figure 6. The dark signals shall be separately integrated and added together to obtain one dark signal D = D1 + D2. The data shall be gathered in three linear ranges. The 2 MSB of each data word shall contain two bits of range data (1..3, MSB first), followed by 14 bits of radiance data for that range. The upper and lower limits of the radiance for each range shall have the nominal values given in Table 16. The values measured for all three ranges shall be transmitted in diagnostic and calibration modes. In the SCAN mode, only the normal range is transmitted (as selected on board to provide the required radiometric resolution) except for the nadir scene where all three ranges are transmitted. The slope (gain) for all ranges in common may be adjusted in flight with the PMT gain-adjustment command.

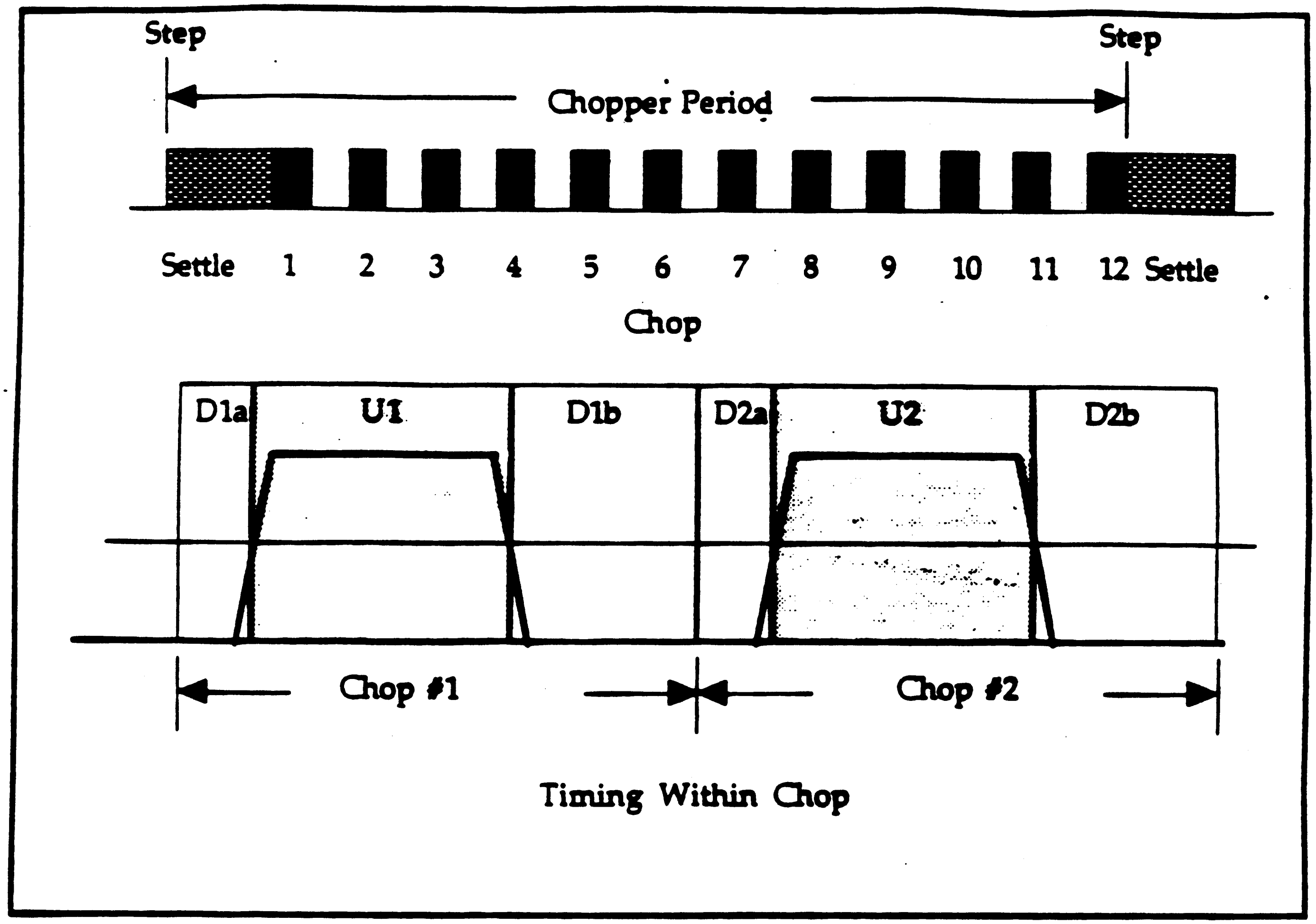

Figure 6. Scanner-Chopper Synchronization and Light and Dark Integration Periods.

Table 16. Photomultiplier Data Ranges.		
Range	Total Range ergs/cm^2-sr-nm-s	Normal Range ergs/cm^2-sr-nm-s
1	0 - 5	0-5
2	0 - 50	5-50
3	0 - 500	50-500

3.2.1.5.3.5.3 **Normal Science Data Record.** Each data sample shall consist of one complete wavelength scan (chopper) cycle. This mode shall be used in Standby, Scan, and Solar Calibration Mode. Each radiance reading shall consist of the sum of the two chops for that band (subscript indicates chop number):

$$R = U_1 - (D1_1 + D2_1) + U_2 - (D1_2 + D2_2).$$

Note: $D1_i + D2_i$ are the dark signal measurements from the same VFC range as the U_i.

Only the PMT data giving the best radiometric resolution shall be telemetered. Each word shall consist of 2 range bits (most significant) followed by 14 bits of radiance data. The data format shall be as shown in Table 17.

Table 17. Normal Science Data Record. Data for each scene, 16 bits per radiance reading (range = 2 MS bits)		
Data Item	Bit Position	No. of Bits
360.0 nm PMT total radiance	0	16
339.8 nm PMT total radiance	16	16
331.2 nm PMT total radiance	32	16
317.5 nm PMT total radiance	48	16
312.5 nm PMT total radiance	64	16
308.6 nm PMT total radiance	80	16

3.2.1.5.3.5.4 **Calibration Science Data Record.** Each data sample shall consist of one complete wavelength scan (chopper) cycle. This mode shall be used in Wavelength Monitoring and Electronic Calibration Modes only. The radiance for each chop shall be transmitted separately as

$$R = U - (D1 + D2).$$

All data ranges shall be telemetered. Each word shall consist of 2 range bits (most significant) followed by 14 bits of radiance or ECAL signal data. The signed radiance value is contained in Bits 0 - 13 of the chop radiance. Bits 14 and 15 contain the electrometer range used to take the radiance readings. The data format shall be as shown in Table 18.

Table 18. Calibration Science Data Record. Data for each scene, 16 bits per radiance reading (range = 2 MS bits)		
Data Item	**Bit Position**	**No. of Bits**
Chop 1, range 1, 312.5 nm Chop Radiance	0	16
Chop 1, range 2, 312.5 nm Chop Radiance	16	16
Chop 1, range 3, 312.5 nm Chop Radiance	32	16
Chop 2, range 1, 312.5 nm Chop Radiance	48	16
Chop 2, range 2, 312.5 nm Chop Radiance	64	16
Chop 2, range 3, 312.5 nm Chop Radiance	80	16

3.2.1.5.3.5.5 **Diagnostic Science Data Format.** This format shall be used in the Diagnostic Mode, and shall consist of groups of 12 successive telemetry packets. Each data sample shall consist of one complete wavelength scan (chopper) cycle. Because 12 times as much data is collected during one diagnostic mode scan line, data shall be transmitted only once every 12 scan lines. Each group of 12 packets shall have the same time stamp. The light, U, and dark, D = D1 + D2, values shall be transmitted separately for each range and each chop. Each word shall consist of 2 range bits (most significant) followed by 14 bits of radiance data.

The data format shall be as shown in Table 19. Only the data for every 12th scan shall be telemetered. The data for the intervening scans shall be discarded. The first packet for a scan shall contain value #1 and the 12th packet shall contain value #12.

Table 19. Diagnostic Mode Science Data Record. Data for each scene, 16 bits per radiance reading (range = 2 MS bits)		
Field Description	**Bit Position**	**No. of Bits**
360.0 nm Value #1 -12	0	16
331.2 nm Value # 1 -12	16	16
322.3 nm Value # 1 -12	32	16
317.5 nm Value # 1 -12	48	16
312.5 nm Value # 1 -12	64	16
308.6 nm Value # 1 -12	80	16

3.2.1.5.3.5.6 **Memory Dump Science Data Format.** This format shall be used to telemeter selected memory contents. The first data record in the science data shall contain the address, the number of bytes in the packet, and the first 10 bytes of data; subsequent records, as required, shall contain 12 bytes of data located at the indicated bit position relative to the beginning of the data record, as shown in Table 20.

Table 20. Memory Dump Mode Science Data Record.

Field Description	Bit Position	No. of Bits
First Data Record:		
Address of first memory byte in this packet	0	16
Memory segment (see Memory Dump Mode Command)	16	8
Number of memory bytes in this data packet	24	16
Memory bytes 0 - 6	40	56
Subsequent Data Records:		
12 Memory bytes	0	96

3.2.1.5.3.5.7 **Empty Science Data Format.** The empty science data format shall be used when science data is not being generated. The entire science data section shall be filled with zeros.

3.2.1.5.4 **Passive Analog Telemetry.** The temperature of the points listed below shall be monitored by temperature sensors powered from the spacecraft. Thermistors shall be 300Ω ± 1 percent at 25° C. Other points shall be monitored as part of the engineering data stream.

- Spacecraft Interface.
- Diffuser Housing (thermistor located outside the carousel area and vented).
- Monochromator Housing.
- Lower Housing (Motor Area).
- +Y Side Radiator.
- -Y Side Radiator.
- Lower Housing Radiator.

3.2.1.5.5 **Active Analog Telemetry.** The TOMS input power bus power shall be monitored with an isolated active telemetry monitor with an accuracy of ±5 percent or better. The scale factor, bandwidth, output impedance, and ground isolation shall be in accordance with the specification of Table 3E herein.

3.2.1.6 **Spatial Scanning.** The TOMS shall perform a cross-course step-scan with a total field of view designed for contiguous global coverage. Each line scan shall consist of a number of equal-duration step-and-dwell cycles followed by a retrace as shown in Figure 7. The forward scan direction shall correspond to a motion of the IFOV from the -Y to

+Y direction when in the PM ascending node configuration and from the +Y to -Y direction when in the AM ascending node configuration.

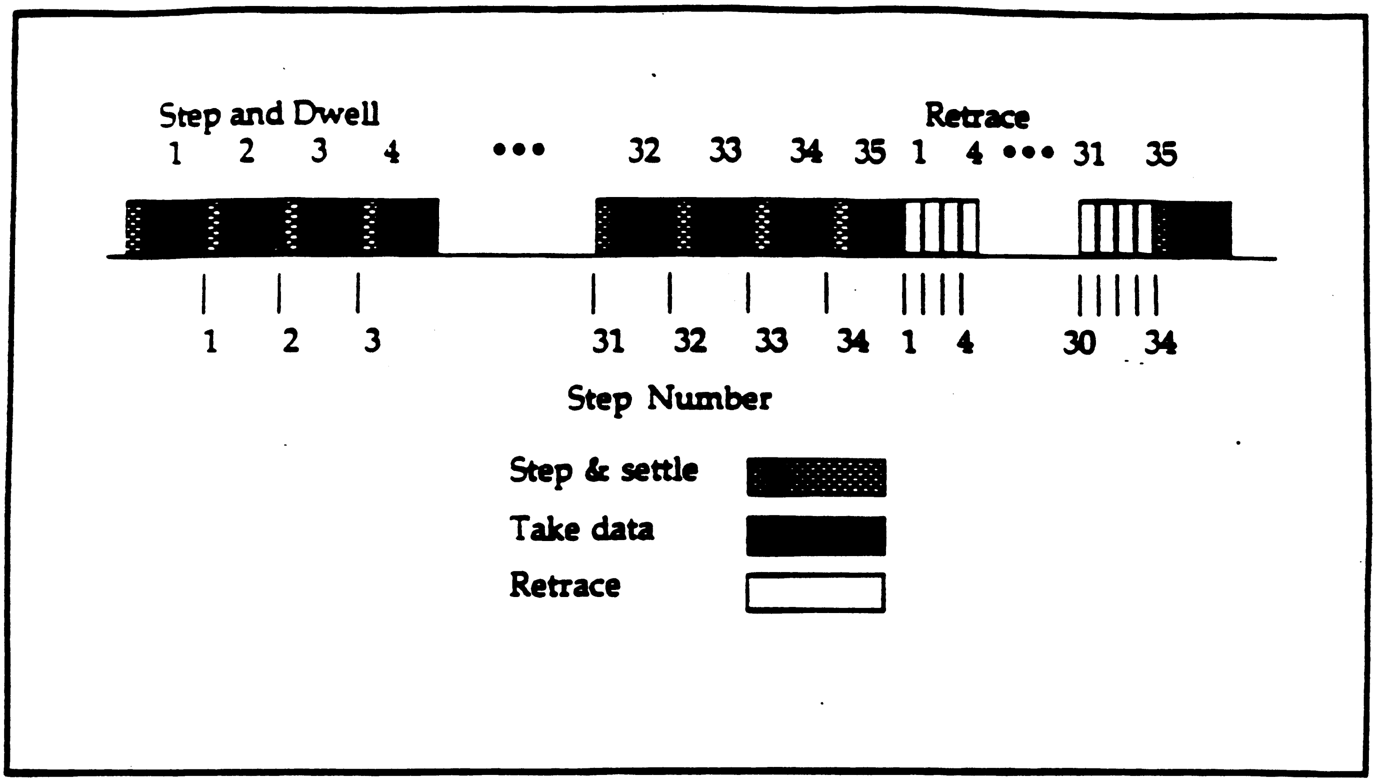

Figure 7. Scan Timing.

3.2.1.6.1 **Instantaneous Half-Power Field of View (IFOV).** The TOMS instrument shall have an instantaneous half-power field of view 3.0±0.1 degrees square for all spectral bands. The IFOV for a given scan position is called a "scene".

3.2.1.6.2 **Full Field of View (FFOV).** Optical definition of the field of view shall assure that 99.95 percent of the energy originates within a 4.0-degree square centered on the nominal IFOV.

3.2.1.6.3 **Clear Field-of-View (CFOV).** No obstruction shall be placed so that it can scatter light into the full field of view. The scan mirror, relay mirror, diffuser, calibration diffuser, and entrance optics shall be sized to encompass the FFOV allowing for beam rotation at applicable scan angles.

3.2.1.6.4 **Step Angle.** The nominal step angle of the scanner shall be equal to 3 degrees.

3.2.1.6.5 **Scan Width.** The number of dwells in a scan shall be selected before launch to provide contiguous spatial coverage between orbits at the equator.

3.2.1.6.6 **Scan Line Period.** The total scan line period shall be an integral multiple of wavelength scan (chopper) cycles with the timing specified as a function of altitude in Table 21 (do not interpolate between altitudes). The scan period (time per line, including retrace) shall be prelaunch-selectable in the range 6 to 8 seconds. The default period shall be selected to provide near-zero underlap at the equator between adjacent scan lines at nadir for a circular orbit at the nominal altitude.

Note that the design limits the available dwell time resolution to 10 milliseconds. For intermediate altitudes, dwell times of 0.16, 0.17, 0.18, and 0.19 seconds are available.

Table 21. Scan Timing vs Altitude.

		Orbital Altitude, km	
Parameter	**Units**	**797**	**955**
Scan dwells (chopper revs)		37	35
Scan steps (moves)		36	34
Scan dwell time	seconds	0.150	0.200
Scan time	seconds	5.550	7.000
Retrace chopper revs		5	4
Total chopper revs/line		42	39
Scan line time	seconds	6.300	7.800
Retrace time available	seconds	0.750	0.800
Minimum retrace rate	steps/second	46.7	41.2
Retrace rate	steps/second	50	50
Integration time	seconds	0.118	0.1575
Time/chop	seconds	0.0103	0.0137
VFC Clock	KHz	800	600

3.2.1.6.7 **Cross Scan Accuracy.** The IFOV centerline shall remain in a plane perpendicular to the instrument x-axis during the 111° step scan within ± 0.15°. This shall be measured with a resolution of 0.03° maximum. This error shall not accumulate beyond the effective width of an IFOV element over the instrument lifetime. The above scan accuracies shall be either inherent in the scanning assembly or sensed and corrected.

3.2.1.6.8 **Scan Rate Stability.** The commanded stepping rate within a line scan shall not vary more than ±3 percent.

3.2.1.6.9 **Scan Repeatability.** The repeatability of the line-scan as defined by the centers of the nominal IFOVs making up a line scan and the x-axis alignment target of the TOMS shall be within 0.3 degrees.

3.2.1.6.10 **Diffuser Look.** The scanner shall be capable of viewing the selected diffuser with the accuracy and repeatability listed in Table 3.

3.2.1.6.11 **Source Look.** The scanner shall be capable of viewing the reflectance calibration source with the accuracy and repeatability listed in Table 3.

3.2.1.6.12 **Scanner Stow Position.** A scanner position shall be provided in which the scan mirror is protected from sunlight and the entrance slit is dark. Signal levels from exposure of the instrument to direct sunlight at any angle shall not exceed full scale when the scanner is in the stow position. This position shall also be used to protect the scan mirror from contamination. A hermetic seal shall not be used.

3.2.1.6.13 **Scan Encoder.** The scan position shall be indicated by an absolute digital encoder with a resolution of one scan step or better. Scan encoder output codes shall be per Table 12.

3.2.1.6.14 **Scan Synchronization.** The step scan motor drive pulses shall be synchronized with the wavelength scan as shown in Figure 6 with a maximum instability of ± 0.05 percent of the scene viewing time, non-cumulative.

3.2.1.7 **Diffusers.** The TOMS instrument shall be provided with a minimum of two ground aluminum reflection diffuser plates, prepared as specified in Section 3.4 below, for determination of the response of the TOMS to incident solar radiation.

3.2.1.7.1 **Diffuser Mounting.** The active diffuser plate shall be mounted or deployed in a position that fills the projected full field of view of the instrument at a scanner position. The diffuser shall be mounted or retractable to a position that does not interfere with normal earth observations. The diffuser must have a clear FOV to the sun at one of the earth day/night terminators. Means shall be provided for protection from contamination or exposure to direct sunlight when a plate is not in use for calibration. The protective cover shall be designed to remain closed when the instrument is unpowered, including orbital flight and the launch. The diffuser plates shall be used as reference and working plates for the purpose of providing a control on optical performance degradation through surface contamination. Both shall be protected from exposure. The protective cover may serve as a contamination reference surface with known diffuse reflection properties.

3.2.1.7.2 **Diffuser Heating.** To prevent contamination the diffusers shall be heated to a temperature no lower than the bulk of the instrument but less than 30° C. The diffusers shall be heated at all times in orbit as long as diffuser heater power is supplied, whether the TOMS is on or off.

3.2.1.7.3 **Diffuser Stray Light.** The diffuser shall be shaded to prevent illumination by sources other than the sun, including light reflected from other instrument components, either by single or multiple reflection off the diffuser or by direct reflection into the entrance optics. The baffle used shall shade the diffuser from any sources of light outside the clear field of view defined in Figures 4A, 4B and 4C. The diffuser irradiance from other sources shall not exceed 1.5 percent of the diffuser irradiance due to the primary source.

3.2.1.7.4 **Reflectance Calibrator.** An in-flight reflectance calibration system shall be provided which is capable of measuring changes in the ratio of reflectivities of the diffuser plates, at the TOMS wavelength pairs, with a relative standard deviation of 0.3 percent (goal) lifetime. Calibrations can be conducted as frequently as once per orbit (subject to spacecraft power limitations).

3.2.1.8 **Spectral Measurements.** The TOMS instrument shall contain a spectrometer, shuttering system, and photodetector and associated electronics capable of resolving the wavelength band fluxes specified herein, with spectral purity and stray light and dark current rejection adequate for meeting the specifications listed in this section.

3.2.1.8.1 **Wavelength Range.** The TOMS shall operate within the wavelength range from 308.6 to 360 nm.

3.2.1.8.2 **Wavelength Bands.** Six discrete spectral bands with nominal center wavelengths listed in Table 22 shall be provided by the TOMS spectrometer.

Table 22. TOMS Wavelengths and Nominal Radiance Limits (Radiance in ergs/cm2-sr-nm-s)

Band #	Center Wavelength	Maximum Radiance	Minimum Radiance
1	360.0 nm	400	10
2	331.2 nm	310	5
3	322.3 nm	203	1.8
4	317.5 nm	170	0.7
5	312.5 nm	110	0.4
6	308.6 nm	55	0.4

3.2.1.8.3 **Wavelength Pairs.** The wavelength pairs in Table 23 will be used for data processing. The instrument design shall minimize any errors in the relative radiance and irradiance measurements in the wavelength pairs.

Table 23. TOMS Wavelength Pairs

Pair	Band #s	Usage
A	5 - 2	Low-latitude ozone
B	4 - 2	Mid-latitude ozone
C	3 - 2	High-latitude ozone
D	6 - 5	Calibration drift; low latitudes only

3.2.1.8.4 **Spectral Bandpass.** The TOMS spectrometer shall have a full width, half maximum spectral bandpass of 1.0 nm+0.3 nm-0.0 nm for all bands over its wavelength range. The instrument transfer function shall be determined for each of the wavelength bands from the band center to the 1 percent relative transmission points on both sides of the band. See notes in Section 6 relating to bandpass measure.

3.2.1.8.5 **Wavelength Accuracy.** The centers of each spectral band shall be within 0.10 nm of the specified wavelength for wavelengths less than 340.0 nm and within 0.20 nm for wavelengths greater than or equal to 340.0 nm. Each center wavelength shall be measured to a precision of 0.05 nm.

3.2.1.8.6 **Wavelength Stability.** The TOMS spectrometer shall maintain wavelength stability of the primary ozone measurement band numbers 4, 5, and 6 (Table 22) within 0.005 nm in the orbital operating environment. The ozone reference wavelengths and the surface reflectivity wavelength (bands 1, 2, and 3) require a wavelength stability of 0.01 nm.

3.2.1.8.7 **Wavelength Scan.** The TOMS shall measure the radiance of all the specified wavelength bands within the dwell time of each scanner position as shown in Figure 6. The chop numbers from 1 to 12 shown shall correspond to Bands 1, 2, 3, 4, 5, 6, 6, 5, 4, 3, 2, 1 respectively.

3.2.1.8.7.1 **Instantaneous Field-of-View Registration.** The angular fields of view for each of the six wavelengths shall be registered within 0.1 degrees.

3.2.1.8.7.2 **Image Motion Compensation.** The wavelength scan shall consist of a repeating sequence such that image motion effects tend to cancel to 1st order in the ratio of radiances for the pairs of wavelengths defined below. The difference in the centroids of the two members of each pair shall be less than 0.1 degrees. See notes.

3.2.1.8.8 **Wavelength Repeatability Monitor.** A wavelength repeatability monitor (WRM) shall provide in-flight wavelength calibration of the TOMS spectrometer. The wavelength calibration relative to the pre-launch laboratory calibration shall be monitored by means of a spectral line emission source(s) having one or more lines near the TOMS spectral region and a means for generating a wavelength scan of the line(s). The WRM shall detect a shift of 0.01 nm at the wavelength(s) of the spectral line source(s). The temperature(s) of the light source(s) shall be monitored.

3.2.1.9 **Radiometric Characteristics.** Measurements of the radiances in the six spectral bands shall meet the following requirements.

3.2.1.9.1 **Dynamic Range.** The design maximum radiance shall be 500 ergs/cm^2—sr—nm—s. The maximum expected earth radiance is 400 ergs/cm2-sr-nm-s at 360.0 nm for a solar zenith angle = 0°, scan angle = 0°, R= 1, P = 1 atm condition (see 6.1 for definitions of symbols). The minimum practical earth radiance at total ozone retrieval wavelengths is 0.40 erg/cm^2—sr—nm-sc at 312.5 nm, obtained at the solar zenith angle SZA = 88°, scan angle = 0°, R = 0.6, p = 1 atm conditions. The TOMS spectrometer dynamic range shall be designed to measure both scene radiance and/or solar irradiance over the maximum and minimum expected signal levels presented in Table 22.

3.3.2.1.9.2 **Radiometric Linearity.** The response of the radiometric system shall be characterized by fit functions which make it possible to calculate the instrument radiometric response (normalized counts/watt) over the full dynamic range to within $\pm0.5\%$. The corrected slope of the output response versus signal level shall remain constant within 2 % from minumum radiance to maximum radiance. The hysterisis of the PMT detector shall be measured.

3.2.1.9.3 **Radiometric Repeatability.** The corrected mean response of the TOMS radiometric system shall be repeatable to better than 1 percent while viewing the same source under the same conditions but separated in time by at least 24 hours.

3.2.1.9.4 **Signal-to-Noise Ratio.** The signal-to-noise (S/N) ratio shall be greater than 30 at the minimum radiance of 0.40 erg/cm2-sr-nm-s. Improved atmospheric measurements will be obtained at higher light levels.

3.2.1.9.5 **Spectral Stray Light.** When the TOMS instrument is viewing the sunlit earth from space, the total contribution by all unwanted wavelengths to the signal produced by radiation defined by the bandwidth of any TOMS spectral band shall be less than 0.5 percent.

3.2.1.9.6 **Radiometric Resolution.** The signal conditioner, digitizer, and data compression (if used) shall provide radiometric data with a precision of no worse than 0.2 percent of signal (9 bits).

3.2.1.9.7 **Band-to-Band Crosstalk.** No more than 0.1 percent of the signal in any band shall result from crosstalk between bands.

3.2.1.9.8 **Dark Current Rejection.** The instrument shall provide for rejection of dark current and instrument offset by use of optical chopping. See notes. The signal-to-noise ratio (S/N) shall be greater than 30 in Band 5 when the TOMS is subject to peak trapped radiation. At this point the Band 5 radiance shall be 2.0 erg/cm^2—nm—s or greater.

3.2.1.9.9 **Single-Event Upsets.** Design of the instrument shall be resistant to single-event upsets such that no damage occurs and data loss is limited to no more than the equivalent of one scan per orbit.

3.2.1.10 **Polarization Sensitivity.** The TOMS instrument shall be equipped with optical depolarizer(s) such that the residual detector polarization sensitivity to the incident radiation will be reduced to less than 5 percent over the operational range of angles and wavelengths. The polarization sensitivity is defined as:

$$P=\frac{(I_{max}-I_{min})}{2\,(I_{max}+I_{min})}$$

where I_{max} and I_{min} are the maximum and minimum values of intensity measurements of the TOMS instrument resulting from rotating a total linear polarizer between the instrument and an unpolarized light source.

3.2.1.11 **Magnetic Field Sensitivity.** A change in the ambient DC magnetic field of ± 1 gauss in any direction shall not change the output signal more than ± 0.05 percent.

3.2.1.12 **Temperature Coefficient of Response.** The end-to-end temperature coefficient of responsivity (radiance to digital output) shall not exceed ± 4 percent (40000 ppm) per °C).

3.2.2 **Physical Characteristics.**

3.2.2.1 **Mass.** The mass of the TOMS instrument shall not exceed 35 kg, including thermal blankets and mounting hardware to the spacecraft.

3.2.2.2 **Resonant Frequency.** The minimum fundamental resonant frequency of the TOMS instrument shall be greater than 100 Hz in any orthogonal direction when mounted to a rigid structure.

3.2.2.3 **Uncompensated Angular Momentum.** The TOMS total instantaneous peak angular momentum component along any axis shall not exceed 0.01 newton-meter-second.

3.2.2.4 **Power.** The orbital average power during the normal operating modes shall be 14 watts or less, excluding operational heater power. Maximum heater power shall be as follows:

a. Operational Heaters: 8.0 W.
b. Diffuser Heater: 2.0 W.
c. Survival Heater: 10.0 W.

3.2.2.5 **Grounding and Shielding.** Grounding and shielding requirements are as follows.

3.2.2.5.1 **Input Power Isolation.** The spacecraft input power return shall be isolated from the housing and from TOMS signal grounds by at least 1 megohm.

3.2.2.5.2 **Output Power Isolation.** TOMS FM-4 signal returns (all lines) shall be DC isolated from the housing by at least 10 Megohms DC resistance. TOMS FM-3 signal returns (all lines) shall be shorted to chassis close to the VFC circuits. (See LVS Specification, 71-0189, for more details on grounding). Separate analog and logic supply buses shall be used, and grounded together in the neighborhood of the analog-to-digital conversion circuits.

3.2.2.5.3 **Local Shields and Returns.** Critical analog circuits (including but not limited to the electrometers, chopper speed control, phase reference pickup, high voltage control amplifier) shall be shielded from other circuits and the housing by Faraday shields connected to local analog signal ground. Separate ground planes shall be used under these circuits, tied to local analog ground. Logic circuits shall have ground planes tied to logic ground. If there are thermal planes, they may be connected to chassis ground but shall be shielded from sensitive circuits. For details see Power Supply Characteristics below.

3.2.2.5.4 **Grounding Provision.** A thread insert and fastener shall be provided on the TOMS instrument mount for grounding purposes (See Figure 5A).

3.2.3 **Reliability (Lifetime).** The TOMS shall be designed for a minimum lifetime of two years in orbit.

3.2.4 **Maintainability.** Preflight maintainability requirements shall be in accordance with GSFC TOMS-910-90-001.

3.2.5 **Environmental Characteristics.** Environmental conditions for the TOMS instruments may vary between launch vehicles and spacecraft. The TOMS shall be designed to meet the requirements of this specification during and after exposure to the environments specified herein.

3.2.5.1 **Transportation, Storage and Handling (Nonoperating).** The TOMS shall operate and meet the requirements of this specification after exposure to any combination of the following environments while packaged in the TOMS shipping containers.

3.2.5.1.1 **Ambient Air Temperature.** The ambient temperature range shall be -10 to +40 °C, maximum transient 5 °C per hour.

3.2.5.1.2 **Ambient Pressure.** The ambient pressure range shall be 400 Torr to 795 Torr.

3.2.5.1.3 **Humidity.** The relative humidity shall be in the range 10 to 100 percent relative, no internal condensation permitted.

3.2.5.1.4 **Static Acceleration.** Maximum semi-steady state accelerations shall be limited to 3g in any direction.

3.2.5.1.5 **Transient Shock and Vibration.** Shipping and storage containers and handling procedures shall be designed and implemented to protect the TOMS at a 6g fragility factor.

3.2.5.1.6 **Cornerwise Drop.** Shipping and storage containers and handling procedures shall be designed and implemented to protect the instrument when the container is dropped in accordance with FED-STD-101 Method 5005.1 Level B.

3.2.5.2 **Functional Test, Checkout and Prelaunch Operations.** The TOMS shall operate and meet the requirements of this specification during and after exposure to any combination of the following environments.

3.2.5.2.1 **Ambient Air Temperature.** The ambient temperature range shall be 0°C to +40°C, transient 5 °C per hour.

3.2.5.2.2 **Ambient Pressure.** The ambient pressure range shall be less than 10^{-5} Torr or 795 Torr.

3.2.5.2.3 **Humidity.** The relative humidity shall be controlled in the range 40 to 60 percent, no condensation permitted.

3.2.5.3 **Launch and Post-Launch Operations (Non-Operating).** The TOMS shall operate and meet the requirements of this specification after exposure to any combination of the following environments.

3.2.5.3.1 **Launch Temperature.** The launch and post-launch non-operating temperature range at the TOMS S/C interface shall be -30°C to +55°C with survival heater(s).

3.2.5.3.2 **Launch Pressure Change.** During the launch, the ambient pressure shall decrease from a maximum of 790 Torr to 1 x 10^{-10} Torr or less at a maximum rate of 18 Torr per second.

3.2.5.3.3 **Acoustics.** The recommended acoustic vibration spectrum is listed in Table 24. There will be no acoustic vibration test at the instrument level.

3.2.5.3.4 **Random Vibration.** The random vibration test spectrum shall be in accordance Table 25.

3.2.5.3.5 **Sinusoidal Vibration.** The protoflight sinusoidal vibration test spectrum shall be in accordance with Table 26.

3.2.5.3.6 **Shock.** The shock test response spectrum shall be in accordance with Table 27 or as specified by individual spacecraft requiremments with tests performed at spacecraft level.

3.2.5.3.7 **Acceleration.** The TOMS instrument shall be designed to withstand the limit loads stated in Table 28 in each of the three orthogonal axes of the instrument, a single axis at a time. No detrimental permanent deformation shall occur when tested to 1.25 times the limit loads. A detailed stress analysis shall show positive margins of safety at 1.4 times limit load for all ultimate failure modes.

3.2.5.4 **Orbital Operations.** The TOMS shall be designed to operate and meet the requirements of this specification during exposure to any combination of the following environments.

3.2.5.4.1 **Temperature.** The operating temperature range for the instrument shall be -10°C to +30°C, measured at the spacecraft side of the mounting interface.

3.2.5.4.2 **Pressure.** The orbital pressure shall be $< 1 \times 10^{-6}$ Torr.

3.2.5.4.3 **Space Radiation.** The worst-case mission charged-particle environment shall be as shown in Figure 1 through Figure 19 of the Radiation Environment for the TOMS Mission (see Applicable Documents section).

3.2.5.4.3.1 **Radiation Dose.** Radiation dose as a function of shielding shall be in accordance with Figures 14 and 15 of the Radiation Environment for TOMS Missions. The TOMS design total absorbed dose over two years (assumes 100 mils spherical aluminum shielding) requirement is 20 kRad (Si).

3.2.5.4.3.2 **Peak Orbital Flux.** Peak instantaneous proton flux (in the SAA) for particles with energy greater than 1 MeV is 4×10^4 particles/cm^2/sec.

3.2.5.4.4 **Orbital Microphonic Vibration Levels.** The amplitude of random vibration acceleration levels shall not exceed + 6 db/octave from 5 to 10 Hz and .01 g^2/Hz from 10 to 200 Hz.

Table 24. Recommended Acoustic Test Levels		
One -Third Octave	Noise Level (dB) re: 0.00002 Pa	
Center Frequency (Hz)	Qualification	Acceptance
25	122	119
32	124	121
40	126	123
50	127	124
63	129	126
80	130	127
100	132	129
125	134	131
160	135	132
200	136	133
250	136	133
315	135	132
400	134	131
500	133	130
630	132	129
800	131	128
1000	130	127
1250	128	125
1600	126	123
2000	124	121
2500	121	118
3150	118	115
4000	115	112
5000	114	111
6300	113	110
8000	112	109
10000	110	107
Overall:	145	142
Duration:	60 to 120 seconds*	60 seconds

* Protoflight Qual = 60 seconds;

Table 25. Random Vibration Test Levels - All Axes		
	Power Spectral Density (g^2/Hz)	
Frequency Range (Hz)	Qualification	Acceptance
20 - 40	+6 dB/Oct	+6 Db/Oct
40 - 1000	0.08	0.036
1000 - 2000	-12 Db/Oct	-12 dB/Oct
Overall Level	10.1 g rms	6.8 g rms
Test duration	1 or 2 min/axis*	1 min/axis

* Protoflight Qual = 1 min/axis;

Table 26. Protoflight Sine Vibration Levels - All Axes		
	Vibration	
Axis	Frequency Range (Hz)	G_o-p
Longitudinal x - axis	5 - 10.8 10.8 - 40 40 - 80 80 - 100	12.7 mm D.A. 3 4 1
Lateral y - axis	5 - 17.7 17.7 - 30 30 - 50 50 - 80 80 - 100	12.7 mm D.A. 8 6 5 1
Lateral z - axis	5 - 19.8 19.8 - 30 30 - 80 80 - 100	12.7 mm D.A. 10 8 1
Sweep Rate: 4 octaves/minute		

Table 27. Protoflight Shock Levels - All Axes	
	Shock Response Spectrum (g)
Frequency Range (Hz)	Qualification
100 - 800	+8 dB/oct
800 - 4000	300

Table 28. Design Limit Loads Acceleration (g's) *		
X	Y	Z
± 15.0	± 15.0	± 15

* Single Axis at a time.

3.3 **Design and Construction.**

3.3.1 **Parts, Materials, and Processes.**

3.3.1.1 **Electrical, Electronic, and Electromechanical (EEE) Parts Selection.** Selection and derating of EEE parts shall be in accordance with GSFC-303-TOMS-002.

3.3.1.2 **Material and Process Control.** Material and process selection and control shall be in accordance with GSFC-303-TOMS-002.

3.3.2 **Electromagnetic Compatibility.** The electromagnetic compatibility design precautions in GSFC-TOMS-910-90-001 shall be followed. The following default specifications generally follow the MIL-STD-461C requirements for class A2a equipment. The tests and the test limits are summarized in table 28b below.

3.3.2.1 **Conducted Susceptibility.** The TOMS shall operate within specification over the range of input voltage with superimposed ripple, and spikes at the levels specified in Method CS01, CS02 and CS06 in Table 28b below.

Table 28b. Electromagnetic Compatibility Tests

TEST	TEST NAME	FREQUENCY RANGE	TEST LIMITS
CE01(1)	Conducted Emissions, Power Leads	30Hz to 50KHz	MIL-STD-461
CE03(1)	Conducted Emissions, Power Leads	15KHz to 100MHz	MIL-STD-461 Narrow Band Emissions
CE11(1, 2)	Voltage Noise on Power Lines	DC to 10MHz	$\leq$ 14mV Zero to Peak (Steady State With no Heaters)
CE13(1, 2)	Current Noise on Power Lines	N/A	$\leq 1.25 \times I_{steady\ state\ max}$
CE14(1, 2)	Transient Current (After Initial In-rush)	N/A	$\leq$ 2A
CE15(1, 2)	In-Rush Current at Turn-On	N/A	$\leq$ 2A
RE02	Radiated Emissions, E-Field	150KHz to 1GHz	Modified MIL-STD-461
RS03	Radiated Susceptibility, E-Field	100MHz to 1GHz	4 V/m

CS01[1]	Conducted Susceptibility, Power Leads	20Hz to 20KHz	1V rms
CS02[1]	Conducted Susceptibility, Power Leads	50KHz to 400MHz	MIL-STD-461
CS06[1]	Conducted Susceptibility, Spikes, Power Leads	2V Spikes Rise: 1msec Fall: 1msec	

(1) These tests shall be performed once at the low voltage supply level and once at the instrument level.

(2) These tests have been assigned numbers using the MIL-STD terminology, but they are not part of MIL-STD-461/462.

3.3.2.2 **Radiative Susceptibility.** The TOMS shall operate within specification when subjected to the radiation levels specified in Table 28b, Method RS03, with a maximum frequency of 1 GHz.

3.3.2.3 **Conducted Interference.** TOMS conducted interference shall not exceed the following limits.

a. **Ripple Current.** Power-line conducted emissions shall not exceed the levels specified in MIL-STD-461C, narrow band emissions, Class A2a, Methods CE01 and CE03.

b. **Voltage Noise (CE11).** Ripple voltage fed back to the primary bus shall not exceed 1mV zero-to-peak per watt of power consumption.

c. **Current Noise (CE13).** Operational transient current noise at steady state operation after turn-on shall not exceed 1.25 times the maximum steady state current and the duration of the transient shall not exceed 50msec. The absolute value of the rate of change of the transient current shall not exceed $1x10^5$ A/sec.

d. **Transient Current (CE14).** Transient current after the initial in-rush shall be $\leq$ 2A with an absolute rate of change of $\leq 2x10^4$ A/sec.

e. **Inrush Current At Turn-On (CE15).** Inrush current shall be limited to 1A and must be damped to $\leq$5% of steady state within 600 msec. In addition, the absolute rate of change ofthe current shall be $\leq 1x10^5$ A/sec.

3.3.2.4 **Radiated Interference.** Radiated emissions shall not exceed the levels specified in MIL-STD-461C, Class A2a, Method RE02, with a maximum frequency of 1 GHz.

3.3.3 **Identification and Marking.** TOMS components shall be appropriately identified by name, serial number, supplier name and contract number using a marking method suitable for use in high vacuum. Like items at the subassembly level shall be serialized. The serial numbers of parts, components and devices shall be recorded on assembly documents at the time of installation. All connectors shall be appropriately labeled with the designators specified in the Appendix.

3.3.4 **Workmanship.** Workmanship requirements shall be as follows.

3.3.4.1 **Hand Soldering.** Hand soldering shall be performed in accordance with NHB 5300.4(3A-1).

3.3.4.2 **Other Processes.** None identified as of this revision.

3.3.5 **Interchangeability.** TOMS instruments shall be interchangeable except for the diffuser and electrical adapters, and for PROMs holding specific flight parameters.

3.3.6 **Safety.** System safety requirements shall be in accordance with GSFC-303-TOMS-002.

3.3.7 **Human Engineering.** Not applicable.

3.3.8 **Standards of Manufacture.** The following requirements shall apply in addition to requirements for the use of approved materials and processes (see 3.3.2)

3.3.8.1 **Cleanliness and Contamination Control.** The cleanliness of all instrument components shall be established and maintained during fabrication, assembly, cleaning, servicing, test, handling, transportation and operational activities in accordance with GSFC-303-TOMS-002. The assembly of all optical components and assemblies, the marriage of the electronics assemblies with the optics module and the assembly of the monochromator housing to the lower housing shall be accomplished in a Class 100,000 controlled environment as defined in FED-STD-209. Temperature shall be controlled at 70 ± 5 degrees F; humidity shall be controlled at $45 \pm 5\%$.

3.3.8.2 **Manufacturing Documentation.** Formal documentation shall be used to control and record the flow of hardware at all times. Starting with the assembled module or printed circuit board, assembly route sheets shall be used to document assembly configuration and all fabrication, assembly, and test operations. The route sheets for all subassemblies shall become part of the end item data package for each assembled component. Log books shall be used to document and control all movements, storage, tests, and other activities pertaining to GFE under contractor control.

3.3.8.3 **Operator Training and Certification.** All critical operations such as soldering, welding and coating which impact the reliability or quality of the TOMS instrument shall be performed by trained, certified personnel.

3.3.8.4 **Electrostatic Discharge Control.** Procedures for electrostatic discharge control shall be in accordance with GSFC-303-TOMS-002 as implemented by 74-0023.

3.3.8.5 **Use of Connector Savers.** Flight connectors shall be protected by connector-savers in accordance with 74-0023. Mating and demating shall be recorded in mate-demate logs.

3.3.9 **Design Constraints.** Designs shall meet the following constraints.

3.3.9.1 **Drafting Standards.** Instrument drawings shall be prepared in accordance with DOD-D-1000, Level 2. Bench checkout unit (BCU), STM and fixture drawings shall be built to Perkin Elmer sketch (SK) level drawings.

3.3.9.2 **Optical Design.** Optical design constraints shall be in accordance with GSFC TOMS 910-90-001.

3.3.9.3 **Mechanical Design.** Mechanical and mechanism design constraints including torque margins shall be in accordance with GSFC TOMS 910-90-001.

3.3.9.4 **Venting.** All subassemblies, cables, blankets, or other components containing lubricants, oils, adhesives, or other materials that have the potential to outgas a substance that could contaminate the diffuser surface shall be vented away from the diffusers.

3.3.9.5 **Thermal Design.** Thermal design of electronics shall assure meeting the worst-case temperature limits for EEE parts as provided in the derating guidelines of Appendix B of PPL-19.

3.3.9.6 **Radiation Shielding Design.** Radiation shielding design shall consist of 100 mils minimum aluminum (or equivalent). Components requiring additional shielding to assure meeting the 2-year life requirement shall use spot shielding.

3.3.9.7 **Electrical Design.** Electrical design constraints shall be in accordance with GSFC TOMS 910-90-001.

3.3.9.8 **Circuit Decoupling.** Circuit decoupling shall assure that power-line voltage variation and noise is rejected to a level comparable to the specified circuit offset or noise level.

3.3.9.9 **Printed Wiring Board Design.** Design of printed wiring boards shall conform to the requirements of MIL-P-55110D (Amendment 4), NHB 5300.4(3J), and NHB 5300.4(3K).

3.3.9.10 **Electrostatic Discharge.** The design shall include applicable provisions for Electrostatic Discharge Control using DOD-HDBK-263 and DOD-STD-1686 as guidelines.

3.3.9.11 **Processor and Logic Design.** Design of processor and instrument logic shall allow for detection and recovery without damage from single-event upset in any external instrument register.

3.3.9.12 **Software Design.** Software design constraints shall be in accordance with GSFC TOMS 910-90-001 and GSFC 303-TOMS-002. In the event of conflict between these two documents, the latter shall govern.

3.4 **Major Component Characteristics.** The performance requirements of the TOMS are most conveniently developed by subsystem, except that interface characteristics listed above are organized by subassembly. Most subsystems fit in a single assembly. The critical characteristics of the major subsystems of the TOMS listed in Table 4 shall be as specified below to establish interfaces and allocate performance requirements.

3.4.1 **Scanner.** The scanner subsystem includes the scan motor and scan encoder, located in the Scanner Assembly. The scan mirror is physically part of this assembly.

3.4.1.1 **Mechanism Design.** The stepping mechanism shall be a direct-drive three-phase Y-connected stepping motor with magnetic detents and a hollow shaft for the light path. The step angle shall be 3.0±0.15 degrees. The shaft inner diameter shall provide a clear aperture sufficient to accommodate the diagonal of the clear field of view.

Note: For a clear FOV of 5.0 degrees, this requires that the diameter be large enough to pass a beam diverging at 7.07 degrees.

3.4.1.2 **Single-Step and Settle Time.** The scan mechanism shall step, settle to and remain within ±0.05 degrees 32 milliseconds after the application of the step signals, with an external load inertia of 250 $gm\text{-}cm^2$ (mirror plus encoder) including scan encoder but not motor rotor.

3.4.1.3 **Retrace Rate.** The scan mechanism shall be capable of retracing at 50 steps per second. Phase lag at the maximum retrace rate shall not exceed one step.

3.4.1.4 **Scan Drive Signals.** The scan drive circuit shall supply the stepping motor drive signals in accordance with Table 36, with the step and retrace rates specified in Table 21. Note that the driver is disabled after settling to conserve power.

3.4.1.5 **Scanner Peak Power.** The scan motor shall draw no more than 10W peak at 22V, measured across the motor terminals.

3.4.1.6 **Scan Encoder.** The scan encoder shall have six tracks with the code listed in Table 12, selected to prevent a single-point failure of the nadir reference. Polarity shall be such that angles identified as negative shall correspond to scanning toward the TOMS -Y axis. Positions shall be provided as shown for diffuser calibration and stow on either side of nadir. Light-emitting diodes (LED's) for tracks A,B,C and for tracks D,E,F shall be in series (two chains of three) with redundant power connections. Current drawn by each of the two LED chains shall not exceed 6 mA at 12V. Output levels shall be CMOS-compatible. See notes in Section 6 for explanation of code.

3.4.2 **Entrance Optics.** The entrance optics, located in the Lower Housing Assembly, shall determine the TOMS IFOV using the monochromator entrance slit as a field stop, and reduce the residual polarization to the required level. A separate baffle shall define the instrument aperture stop. The entrance optics subsystem includes the scan mirror, depolarizer, relay mirror, objective lens, field stop and baffles. The scan mirror is physically part of the scanner assembly, and the field stop is part of the monochromator assembly (the entrance slit). See section 3.1.2.3.3 for alignment requirements for these assemblies.

3.4.2.1 **Clear Aperture.** The entrance optics clear aperture, including tolerances, shall be sufficient to accommodate the diagonal of the clear field of view.

Note: For a clear FOV of 5.0 degrees, this requires that the clear aperture be large enough to pass a beam diverging at 7.07 degrees.

3.4.2.2 **Image Quality.** Distortion or defocusing of the image, variation in transmission, the effects of chromatic aberration, or reflected or scattered light striking the internal surfaces shall not produce an effective monochromator wavelength shift of more than 0.005 nm for any wavelength band.

3.4.2.3 **Transmission.** Transmission including mirror reflectance shall exceed 60 percent (goal) for the TOMS wavelength bands, including the effects of space radiation over the specified lifetime.

3.4.2.4 **Temperature Coefficient of Transmission.** The temperature coefficient of transmission of the entrance optics, including the reflectance of the scan and relay mirrors, shall not exceed 300 ppm/°C.

3.4.2.5 **Entrance Optics Scintillation Efficiency.** Refractive material shall not have a scintillation efficiency for 4 MeV electrons exceeding that of fused silica.

3.4.3 **Diffuser Subsystem.** One of three diffuser surfaces (working, reference, and cover) on the faces of a rotating three-sided diffuser carousel (an equilateral triangular prism) shall be selectable by use of a stepping mechanism for viewing by the scan mirror. The diffuser carousel shall be mounted within a housing. One diffuser surface shall be visible at a time through an aperture in the housing while the other faces are protected. Only the cover diffuser surface shall be exposed in the stow position.

3.4.3.1 **Diffuser Plate Preparation.** Each diffuser plate and all surrounding surfaces in close proximity to the diffuser plate shall be fabricated from 6061-T6 aluminum stock which shall be machined by a process which avoids contamination by oils. The diffuser optical surface shall then be ground with iron-free, pure, 180 mesh, aluminum oxide grit (65 + 35/-25 micron) until a uniform surface is obtained. The surface shall be washed with distilled water, dried with compressed dry nitrogen, then coated with evaporated aluminum 1000 ± 50 Å thick.

3.4.3.2 **Diffuser Size.** Each finished diffuser surface and the diffuser aperture shall have an effective clear aperture at a minimum 10% larger than the projection of the clear field of view of the entrance optics on the diffuser plane. No unfinished part of the diffuser shall be visible through the aperture.

3.4.3.3 **Diffuser Location.** The center of the active diffuser shall be located in the instrument X-Y plane, so that the scan angle is 90 degrees. The active diffuser surface normal shall have direction cosines in the TOMS coordinate system of'

$$(e_x,e_y,e_z) = (1,-1,-1)/\sqrt{3},$$

with the alignment tolerances listed in Table 3.

3.4.3.4 **Diffuser Positioning.** The azimuthal angle of the diffuser shall be repeatable with respect to the scanner as specified in Table 3.

3.4.3.5 **Diffuser Positioning Mechanism.** The stepping mechanism shall be driven by a 3—degree three-phase Y-connected stepping motor with magnetic detents. The mechanism shall position the diffuser carousel within ±0.15 degrees, including the effects of mechanism unbalance in a 1g-field, and motor static friction.

3.4.3.5.1 **Diffuser Mechanism Stepping Rate.** The diffuser mechanism shall step at 25 steps per second with an internal moment of inertia not exceeding 725 gm-cm^2 (including encoder) plus a diffuser carousel inertia not exceeding 150 gm-cm^2 for a total of 875 gm-cm^2.

3.4.3.5.2 **Diffuser Drive Signals.** The motor drive circuit shall supply the stepping motor drive signals in accordance with Table 36.

3.4.3.5.3 **Diffuser Mechanism Peak Power.** The diffuser positioning motor shall draw no more than 10W peak at 22V, measured across the motor terminals.

3.4.3.5.4 **Diffuser Position Encoder.** The diffuser encoder shall have three readout stations separated by 120 degrees, each corresponding to a stable position of the stepping mechanism. Three light-emitting diodes (LEDs) at the read station shall be driven in series with the code listed in Table 13. The working and stowed LEDs shall be wired in series, where the reference LED shall be wired independently. Current drawn by the LED chains shall not exceed 6 mA at 5V each. Output levels shall be CMOS-compatible, low true.

3.4.3.6 **Diffuser Heating.** The diffuser carousel shall be thermally isolated and heated. The heater shall be connected to the spacecraft power bus with no control other than the on/off relay. The heater resistance shall be selected to dissipate 10 Watts at the maximum spacecraft steady-state bus voltage. The maximum spacecraft voltage for FM-3 is 32 Vdc and for FM-4 is 52 Vdc.

3.4.3.7 **Diffuser Baffle.** A baffle shall be used for FM-4 to limit radiation onto the diffuser to that coming directly from the sun during solar calibration.

3.4.4 **Reflectance Calibration Subsystem.** This subsystem shall consist of a reflectance calibration assembly and a remotely-located lamp power supply. The reflectance calibration assembly shall contain a low-pressure mercury-lamp within a lamp housing with exiting diffuser, a heater and a temperature monitor. A phosphor-coated plate shall be mounted within the exit diffusers to serve as a broadband source covering the TOMS wavelength range. The scanner shall view the diffuser being calibrated and the lamp diffuser at the commanded ratio.

3.4.4.1 **Illumination.** Lamp brightness and positioning shall assure that the signal is no greater than 80 percent of full scale in the scan mirror position and that there is a minimum signal to noise ratio greater than 10 at any wavelength band. The lamp assembly shall be mounted so that the normal of the exit diffuser bisects the angle between the diffuser carousel and the scanner, assuring symmetric illumination of the two components.

3.4.4.2 **Accuracy of Illumination.** The average ratio of the illumination of the diffuser carousel and the scanner at 360 nm shall be repeatable to ± 0.5 percent.

3.4.4.3 **Quantizing Accuracy.** The quantizing accuracy (radiometric resolution) for this measurement shall be ± 0.05 percent of signal (with signal averaging).

3.4.5 **Monochromator Subsystem.** The monochromator subsystem shall consist of the housing, collimating mirror, and grating and slit assembly. The monochromator assembly shall also include a temperature sensor on the slit plate and two temperature sensors to measure housing temperature differential on the entrance and exit slit sides, for evaluation of mirror tilt in the direction of dispersion (see Table 9).

3.4.5.1 **Monochromator Design.** The monochromator subsystem shall be designed to select the wavelength bands specified herein with the requisite stray light rejection, wavelength accuracy and stability, and to support the wavelength calibration.

3.4.5.2 **Wavelength Monitor Entrance Slit Location.** Two entrance slits for the 296.7 nm mercury line shall be positioned on the slit plate so that each exit beam is centered on one edge of the 312.5 nm (Band 5) exit slit. The entrance slits shall have a nominal spectral width of 0.625 nm with the inner edges positioned no more than 0.25 nm apart. The actual width and separation of the slits in mm depends on the linear dispersion in mm per nm.

3.4.5.3 **Chopper Track Location.** The optical design shall determine the center of rotation and the radial locations and radial widths of the chopper disk tracks such that the entrance and exit beams are interrupted without vignetting by the chopper, or mixing of the signals from the two wavelength monitor entrance slits.

3.4.5.4 **PRP Slit Location and Size.** The center of the phase reference pickup (PRP) entrance slit may be offset from the monochromator entrance slit as required, provided the chopper slit is offset by the same amount. The width of the PRP entrance slit tangential to the direction of motion of the chopper shall have the same angular width as the chopper PRP slot when viewed from the distance of the virtual image of the receiving phototransistor. The height of the PRP slit shall be sufficient to assure filling the phototransistor aperture in the radial direction.

3.4.5.5 **Monochromator Transmission.** Transmission of the monochromator, including the mirror reflectance and grating efficiency and the exit optics specified further below shall be at least 28 percent.

3.4.5.6 **Temperature Coefficient of Transmission.** The temperature coefficient of transmission of the monochromator (entrance slit to detector) shall not exceed 600 ppm/°C.

3.4.5.7 **Photomultiplier Exit Optics.** The photomultiplier exit optics shall image the grating mask on the photomultiplier photocathode mask to reduce stray light from outside the grating. The size of the mask shall be nominally 9 mm square, with maximum diagonal not exceeding 13 mm.

3.4.5.8 **Exit Optics Stray Light.** Transmitting surfaces shall be coated to reduce reflections and the rear side of the exit slit plate and the interior of the exit optics housing shall be blackened and baffled as required to reduce stray light.

3.4.5.9 **Exit Optics Scintillation Efficiency.** Refractive material shall not have a scintillation efficiency for 4 MeV electrons exceeding that of fused silica.

3.4.6 **Chopper (Wavelength Scanner) Subsystem.** The entrance beam of the monochromator shall be chopped opposite the collimating mirror side by a rotating chopper disk. The chopper shall contain slots which rotate over the monochromator exit slits to pass one wavelength band at a time. The Phase Reference Pickup (PRP) shall consist of a light-emitting diode in the lower housing and a phototransistor in the monochromator, with processing electronics to provide a once-per-revolution index pulse.

3.4.6.1 **Chopper Disk Design.** The chopper disk shall contain tracks for the monochromator entrance slits (main and calibration), for the exit slits for each wavelength band, and for the Phase Reference Pickup. The track layout shall be fixed for all TOMS models. A sector shall be used for scanner step-and-settle, and twelve sectors shall be used for two samples each of the six wavelengths at 50 percent duty cycle. The sequence of wavelength selection slots shall be in accordance with Table 29. This layout was derived from Table 13 to provide 120,000 VFCCLK counts per revolution (0.003 degrees per count). The chopper shall rotate so that the entrance slots pass in front of the monochromator entrance slit in the order given in the table.

Exit angles shall be the supplement of the entrance angles plus an optically-determined allowance for exit aberrations to avoid vignetting the beam.

Slit edge location tolerances shall be ± 0.012 degrees.

There shall be no measurable crosstalk between wavelength monitor entrance slits as a result of the finite radial width of the chopper entrance slots.

3.4.6.2 **Chopper Servo.** The chopper disk shall be driven by a brushless DC motor with an electronic commutator and speed control. Subsystem interfaces shall be as specified in the interface section above. Detailed characteristics of the servo and its components shall be specified in the chopper subsystem specification referenced in Table 4.

3.4.6.2.1 **Chopper Speed Reference (VFCCLK).** The chopper speed shall be controlled by comparing the tachometer output clock TACHSIG with a clock TACHREF derived from the high-frequency crystal-controlled clock VFCCLK used to control the voltage-to-frequency converters.

3.4.6.2.2 **Chopper Phase Reference (PRPREF).** The chopper phase shall be controlled by comparing the falling edge of the Phase Reference Pickup Pulse (PRPSIG) defined below, with the rising edge of the Chopper Phase Reference signal, PRPREF.

3.4.6.2.3 **Chopper Phase Jitter.** The speed control shall assure that the chopper phase jitter at any point does not exceed 400 microradians rms.

Table 29. Chopper Slot Sequence in Azimuth Angles in Degrees Reference position is center of PRP slot			
Slit/Band	**Wavelength, nm**	**Entrance Slot Start**	**Entrance Slot End**
1	360.0	0.000	12.312
2	331.2	24.624	36.936
3	322.3	49.248	61.560
4	317.5	73.872	86.184
5	312.5	98.496	110.808
6	308.6	123.120	135.432
6	308.6	147.744	160.056
5	312.5	172.368	184.680
4	317.5	196.992	209.304
3	322.3	221.616	233.928
2	331.2	246.240	258.552
1	360.0	270.864	283.176
PRP	N/A	339.380	339.620
WRM1	296.7	98.496	110.808
WRM2	296.7	172.368	184.680

3.4.6.2.4 **Chopper Phase Error.** A signed byte (7 bits plus sign) shall be provided that indicates the difference in VFCCLK counts between PRPSIG and PRPREF. The sign shall be positive if PRPREF occurs first. The count shall not carry, but shall lock up at full count. The counter shall be read during the next scanner step interval.

3.4.6.3 **Phase Reference Pickup and Phase Reference Pulse (PRP).** The PRP slot on the chopper shall be used to gate the light beam between a light-emitting diode located in the lower housing and a phototransistor located in the pickup unit in the monochromator.

3.4.6.3.1 **PRP Slot and LED Mask Location and Size.** The center of the PRP chopper slot shall pass over the center of the PRP entrance slit 1.500 degrees of revolution before the leading edge of the first wavelength slot on the chopper is centered over the entrance slit. The PRP slot shall have a width corresponding to 0.24 ± 0.012 degrees in azimuth measured at the center of the slit from the chopper axis of rotation and a radial height of 2 ± 0.2 mm. The width of the LED mask tangential to the direction of motion of the chopper shall have the same angular width as the chopper PRP slot when viewed from the distance of the virtual image of the receiving phototransistor. The radial heights of the slots and mask shall be sufficient to assure filling the phototransistor aperture in the radial direction.

3.4.6.3.2 **PRP Signal Processing.** The PRP shall produce a roughly triangular light pulse with a full width at half maximum of 0.24±0.05 degrees, which shall be processed to produce a logic signal called the PRP signal (PRPSIG). The length of the phase reference signal shall be 100±50 microseconds. The falling edge shall be the active edge.

3.4.6.3.3 **PRP Delay Stability.** The signal shall be processed and the photodiode current regulated to achieve an overall delay stability over the lower housing operating temperature range of ±100 microradians.

3.4.7 **Wavelength Monitor Subsystem.** The monitor shall consist of a mercury lamp illuminating a transmission diffuser. A lens shall collect the diffuse light to illuminate two slits on the monochromator slit plate, selected alternately by the chopper (two samples/revolution). The subsystem and subtier specification shall specify the performance of the lamp, lamp mount, lamp power supply, and illumination system. Diffuser and lens shall be appropriately masked to control stray light that might interfere with meeting the requirements below.

3.4.7.1 **Illumination Uniformity.** The two entrance slits shall be equally illuminated at 296.7 nm within ±2 percent, including all effects of initial misalignments.

3.4.7.2 **Long-Term Illumination Stability.** The ratio of the 296.7 nm illumination of the two entrance slits shall be stable over the instrument life to ±0.5 percent, including all effects of lamp arc wandering, lamp darkening, thermal expansion, and other influences on beam position.

3.4.7.3 **Signal-to-Noise Ratio.** Variation in 296.7 nm signal illumination resulting from all sources of noise, including but not limited to photoelectron statistics, lamp noise, and power supply ripple and noise, shall not exceed ±1 percent of the signal for one wavelength chopper cycle.

3.4.7.4 **Wavelength Monitor Lamp Power.** The power input to the lamp power supply shall not exceed 3.0 W (high line, current limit conditions).

3.4.8 **Photomultiplier Subsystem.** The photomultiplier detector, high-voltage power supply, and at least the first electrometer amplifier shall be integrated into a single assembly. The subsystem shall also include the ranging amplifiers.

3.4.8.1 **Quantum Efficiency.** The quantum efficiency shall be at least 12 percent for any of the TOMS wavelength bands.

3.4.8.2 **Long-Term Stability.** The long-term stability of response shall be ±5 percent per year or better.

3.4.8.3 **Temperature Coefficient of Responsivity.** The end-to-end responsivity, from input radiant power to output pulse count, shall not vary more than ±0.575 percent per °C, including variations in photocathode sensitivity, high voltage, multiplier gain, and electronic gain. See Section 6 notes, Table 40.

3.4.8.4 **Offset Stability.** The end-to-end offset stability shall be better than ± 0.02 percent over orbital temperature variations of ± 0.2°C per orbit (1000 ppm/°C).

3.4.8.5 **Signal Delay Stability.** The delay stability of each signal shall be $\pm$ 10 microseconds.

3.4.8.6 **Delay Matching Between Ranges.** The delays of the different range signals shall be matched to $\pm$ 2.5 microseconds.

3.4.8.7 **Linearity of Response.** As a design goal, the end-to-end variation of gain (output counts / photocathode energy) with signal level shall not exceed ± 0.05 percent over the dynamic range.

3.4.9 **Voltage-to-Frequency Conversion.** Analog-to-digital conversion of the photomultiplier and photodiode signals shall be performed by voltage-to-frequency converters. The binary pulse-amplitude-modulated output signals VFCRNG1, VFCRNG2, and VFCRNG3 shall drive accumulators in the digital interface subsystem.

3.4.9.1 **Resolution.** Resolution shall be at least 14 bits using the reference clock generated by the interface subsystem when up/down counts are accumulated over two chop times.

3.4.9.2 **Synchronization.** The VFC's shall be synchronized by the leading edge of the clock signal VFCCLK listed in Table 33 and the signals VFCTRAN and VFCCOLR (see Figure 8 and related discussion).

3.4.9.3 **Reference Source.** A precision supply shall be used to provide the reference voltage for the photomultiplier analog-to-digital conversion. Separate references shall be used for housekeeping and electronic calibration.

3.4.9.4 **Temperature Coefficient.** The end-to-end conversion gain from analog input to digital output rate shall not vary more than ± 100 ppm per °C. See Section 6 notes, Table 40.

3.4.9.5 **Offset Stability.** The end-to-end offset stability shall be better than ± 0.02 percent over orbital temperature variations of ± 0.2°C per orbit (1000 ppm/°C).

3.4.9.6 **Signal Delay Stability.** The delay stability of each signal shall be $\pm$ 10 microseconds.

3.4.9.7 **Delay Matching Between Ranges.** The delays of the different range signals shall be matched to $\pm$ 2.5 microseconds.

3.4.9.8 **Linearity of Response.** The end-to-end variation of gain (output counts / input signal) with signal level shall not exceed ± 0.05 percent over the dynamic range.

3.4.10 **Electronic Calibration Subsystem.** Precise signal currents shall be injected into the TOMS signal processing chains in addition to the currents normally furnished by the photomultiplier tube and photodiode. This calibration shall be performed at night with the scanner stowed, so that there is no signal from the sensors except DC offsets.

3.4.10.1 **Electronic Calibration Method.** A special-purpose digital-to-analog converter shall produce a precise voltage signal, which shall be chopped with the control signal ECALCLK and fed to the electrometer summing nodes through resistors to produce quasitrapeziodal current pulses. A minimum of seven levels shall be used to test the PMT electrometers, corresponding nominally to radiance levels of 400, 133.3, 40, 13.33,4,1.333, and 0.4 ergs/cm^2-sr-nm-s. Timing shall be the same as when scanning. The ECAL level shall be set once per scan line by a 3-bit command using the optics port. The level shall be changed at the same time that the scanner begins to retrace. ECALCLK timing shall be as specified below.

3.4.10.2 **Electronic Calibration Accuracy.** The calibration shall provide test signal currents accurate to ±0.5 percent over 24 hours and ±10 percent over the operating life.

3.4.11 **Housekeeping Subsystem.** A synchronous voltage-to-frequency converter with multiplexed input shall be used to digitize the analog signals in Table 9. The pulse-modulated output signal HKVFC shall be accumulated in the Electronics Module as specified below.

3.4.11.1 **Multiplexer Channels.** The subsystem shall be capable of measuring up to 32 different voltages using two 16-channel multiplexers. Each multiplexer shall measure its own zero (ground) reference and full-scale.

3.4.11.2 **Input Dynamic Range.** The dynamic range of the subsystem shall be 0 to +5V.

3.4.11.3 **Calibration Accuracy.** Calibration accuracy (Multiplexer inputs TBV1 and TBV2) shall be < ± 17 LSB over the TOMS operating temperature range.

3.4.11.4 **Calibration Offset Drift.** Calibration offset drift shall be < ± 9 LSB over the TOMS operating temperature range.

3.4.11.5 **Synchronizing Clock.** The housekeeping voltage-to-frequency converter shall operate at the VFCCLK frequency specified in Table 33.

3.4.11.6 **Reference Voltage.** The housekeeping subsystem shall contain a precision bias supply, buffered to bias thermistors. The buffer amplifier shall be short-circuit protected at twice the expected current and shall be capable of driving a 4000 ohm load with no more than 0.01 percent loss of regulation. To avoid noise and line drop, separate reference supplies shall be used to provide the reference voltages for other subsystems. The reference voltage shall be measured (see Table 9).

3.4.11.7 **Thermistor Circuit.** Thermistors shall be 30 K±1 percent at 25°C in accordance with GSFC S-311-P-18. Each thermistor shall be connected in series with a bias resistors, with signal taken from the common point. Resistors shall be 37.4K±0.1 percent 1/8 W RNC55H3724BP for maximum sensitivity at +20°C (midpoint of operating temperature range). Thermistors shall be connected to the signal return side and shall not be linearized by additional circuitry. Each thermistor shall be bypassed to signal return with 0.1 microfarads located at the multiplexer input.

3.4.11.8 **Temperature Input Accuracy.** The accuracy of all the multiplexer temperature inputs shall be < | ±32 | LSB at - 20° C and < | ±12 | LSB at +40° C operating temperature.

3.4.11.9 **Temperature Input Drift.** The drift of all the multiplexer temperature inputs shall be < | ±17 | LSB at - 20° C and < | ±7 | LSB at + 40° C operating temperature.

3.4.11.10 **Analog Input Accuracy.** The accuracy of the multiplexer analog inputs (CMV, LV, CMI, HV, & PRPB) shall be < | ±86 | LSB over the TOMS operating temperature range.

3.4.12 **Optics Module Port.** A bidirectional parallel port shall be used to read data and send signals with low synchronization requirements between the optics module subsystems described above and the interface subsystem described below. The analog interface and motor control assemblies shall contain 3-port bidirectional latches (82C55 shall not be used). The signals transferred shall be as listed in Table 30 and the ELM control ports interface signals shall be as listed in Table 31. The HV Gain Adjustment shall have a dedicated byte to reduce the possibility of disturbance.

Table 30. Data Transferred Through Optics Module Port (High True)
Read/Write Frequency: Times per Scan Line or S=Once per Scene

Device Address	Port	Function	Destination	RD/WR Freq	Bits	Position
0	A	HV Gain Adjust (FF=Off)	OPM-AI	<<1	8	0 to 7
0	B	Housekeeping Address	OPM-AI	4	5	0 to 4
0	B	Spare	OPM-AI		3	5 to 7
0	C	ECAL Level (0=Off)	OPM-AI	<1	4	0 to 3
0	C	High Voltage Enable	OPM-AI	<<1	1	4
0	C	Spare	OPM-AI		3	5 to 7
1	A	Scan Encoder	ELM-I/O	S	6	0 to 5
1	A	Chopper Inner Loop Lo	ELM-I/O	S	1	6
1	A	Chopper Inner Loop Hi	ELM-I/O	S	1	7
1	B	Chopper Phase Error	ELM-I/O	S	8	0 to 7
1	C	Diffuser Encoder	ELM-I/O	<<1	3	0 to 2
1	C	Spare	ELM-I/O		1	3
1	C	Reflectance Lamp Enable	OPM-MC	<<1	1	4
1	C	Wavelength Lamp Enable	OPM-MC	<<1	1	5
1	C	Chopper Enable*	OPM-MC	<<1	1	6
1	C	Inner Loop Error Reset	OPM-MC	1	1	7

NOTE: AI: Analog Interface CCA, MC: Motor Control CCA, I/O: Digital I/O CCA

Table 31. ELM Port Signals		
Bit	Control Port (Write Only)	Data Port (Read/Write)
7 (MSB)	Read*	D7
6	Write*	D6
5	A1 Port Select (MSB)	D5
4	A0 Port Select (MSB)	D4
3	Device Select 3 (DS3) (MSB)	D3
2	Device Select 2 (DS2)	D2
1	Device Select 1 (DS1*)	D1
0 (LSB)	Device Select 0 (DS0*) (LSB)	D0
N/A	Microprocessor RESET	N/A

NOTE: Signals DS2 and DS3 are not used.

3.4.12.1 **System Reset.** The system power-on high-true RESET signal shall be transmitted to the remote latches. When a power-on reset occurs, the chopper shall be enabled and the high voltage, calibration lamps and electronic calibration shall be disabled. The high voltage shall be immediately reset to the value stored in backup memory, if valid; otherwise it shall be set to the default value. If a warm boot occurs, the high-voltage register be checked for validity and reset if necessary.

3.4.12.2 **Read/Write Restrictions.** Read/write operations shall occur only during the scanner step and settle time (if once per scene) or after scanner retrace but before the start of the next scan line (if once per line or less).

3.4.13 **Electronics Module Digital Input/Output (I/O) Board.** This subsystem consists of timing logic, the interfaces between the other TOMS subsystems and the central processor, and the bilevel and serial command and data interface with the spacecraft. Spacecraft interface and command format shall be as specified in section 8.1.2. The processor shall control the optical system according to the commands received from the S/C and collect the data as specified herein and assemble the data into packets and transmit as defined herein.

3.4.13.1 **Subsystem Outputs to Optics Module.** The interface subsystem shall generate the signals listed below.

3.4.13.1.1 **Optics Port Control.** The port shall be operated as specified below.

3.4.13.1.1.1 **Optics Port Initialization.** After power-on reset the remote ports shall be initialized to operate as shown in Table 32. Input data from the optics module is not latched; the processor must wait for settling before reading the port after stepping a motor. The chopper phase error is measured once per wavelength scan (chopper revolution) and shall be read during the next scanner step interval. See Figure 7A for OPM-Bus read timing data flow.

Table 32. Remote OPM-Bus Ports Initialization (Data in Hex)							
Device	Port	DS1*	DS0*	A1 PS1	A0 PS0	Data (HEX)	Function
AI	A	1	0	0	0	V V	HV Stored Value
AI	B	1	0	0	1	00	HK Address 0
AI	C	1	0	1	0	00	HVPS, ECAL Off
MC	A	0	1	0	0	None	None (input)
MC	B	0	1	0	1	None	None (input)
MC	C_{lower}	0	1	1	0	None	None (input)
MC	C_{upper}	0	1	1	0	O	Chopper On, Lamps Off

3.4.13.1.1.2 **Remote Port Update and Verification.** After initialization the output ports shall be updated as necessary. The data shall be refreshed at least once per scan line to reject single-event upset.

3.4.13.2 **Reference Signals.** The reference signals listed in Table 33 shall be derived from a 12.00 MHz primary crystal oscillator with a stability of better than 7.5 ppm over the -10°C to 40°C temperature range. The processor clock and peripheral clock PCLK shall be 4.00 and 2.00 Mhz respectively. All signals shall be transmitted with a maximum delay of 0.25 microseconds and with 10 to 90 percent rise and fall times of 0.2 microseconds or less.

3.4.13.2.1 **VFC Reference Clock.** The voltage-to-frequency converter (VFC) reference clock shall be generated from the processor clock by dividing it as shown in Table 33. The frequency of the clock shall be determined by a parameter loaded in PROM. The chopper rotates at 1/120,000 of the VFC clock frequency. The design shall permit division ratios of 15, 16, 17, 18, 19, and 20 as a minimum. Duty cycle shall be 50 ±20 percent.

Table 33. Reference Signals Divide 12 Mhz oscillator frequency by number in divide column					
		797 km		955 km	
Function	Symbol	Divide	Khz	Divide	Khz
VFC clock	VFCCLK	15	800	20	600
VFC color sync	VFCCOLR	See text			
VFC transition sync	VFCTRAN	See text			
Chopper phase reference	PRPREF	1.8E6	0.00667	2.4E6	0.00500
Orbit clock	ORBCLK	239,616	0.05008	239,616	0.05008

3.4.13.2.2 **VFC Synchronization.** The voltage-to-frequency converters shall be synchronized by two signals derived from the VFC clock and demodulation sequence.

3.4.13.2.2.1 **VFC Color Sync (VFCCOLR).** This signal shall be low during the first down-counting period of each chop, as shown in Figure 8. Skew between the triggering rising edge of VFC clock and the corresponding VFCCOLR transition shall not exceed 100 nanoseconds.

3.4.13.2.2.2 **VFC Transition Sync (VFCTRAN).** This signal shall consist of a delayed burst of 24 cycles at twice the chop rate, with the trailing edges synchronous with the transition between up and down counting as shown in Figure 8. Skew between the triggering rising edge of VFC clock and the corresponding VFCTRAN transition shall not exceed 100 nanoseconds.

Note that the VFCTRAN does not have to be a 50% duty cycle waveform as long as the signal meets the requirements specified in Figure 8.

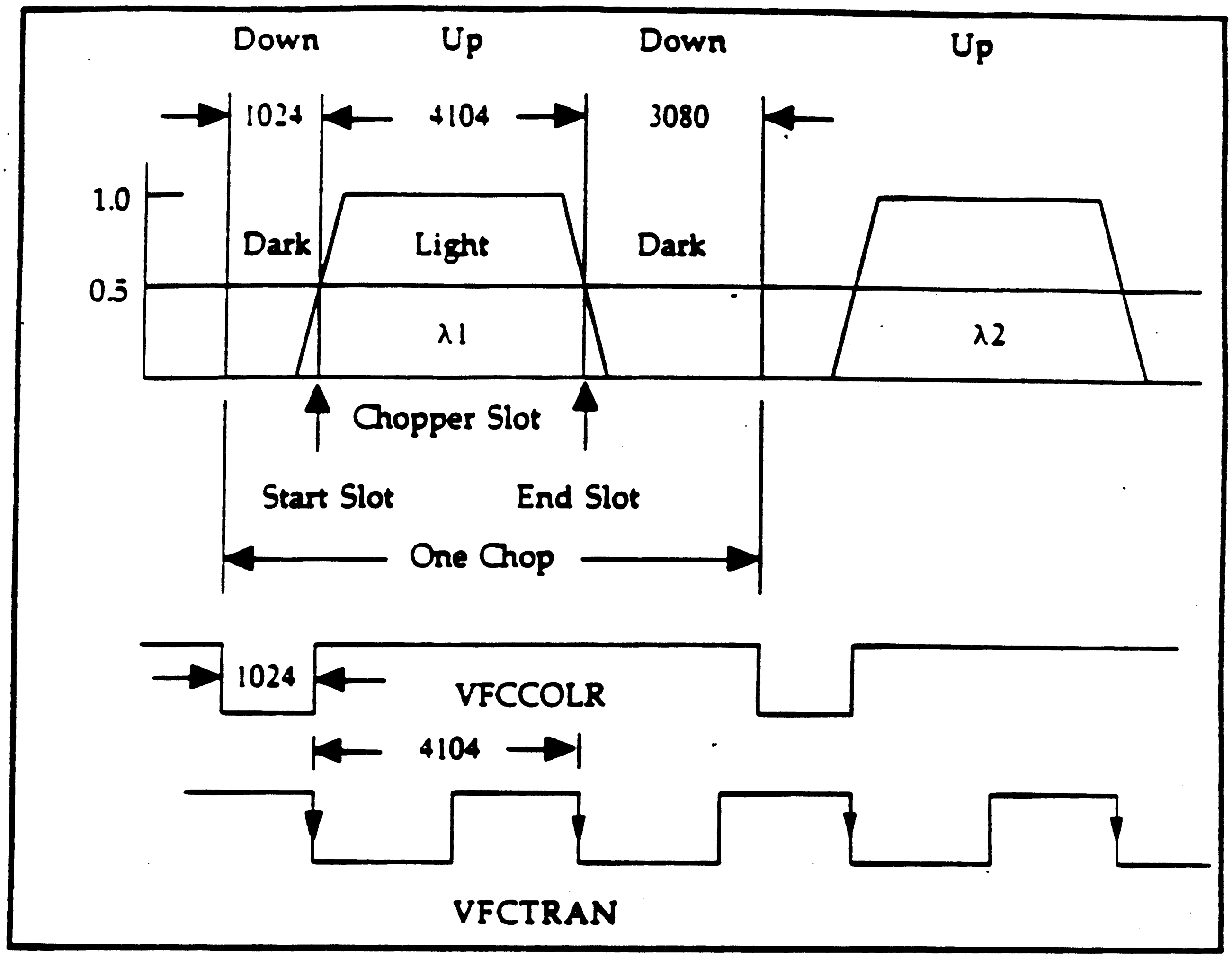

Figure 8. VFC Controls and Demodulation Timing.

3.4.13.2.3 **Chopper Phase Reference (PRPREF).** This signal shall be generated by dividing VFCCLK down to the chopper rotation frequency specified in Table 21. Duty cycle shall be 50±20 percent.

3.4.13.2.4 **Housekeeping Control Signals.** The housekeeping multiplexers shall be programmed with a 5-bit address as shown in Table 9B that changes four times per scan line. The block of four data words thus accumulated shall be identified with a 3-bit block ID code.

3.4.13.2.5 **Electronic Calibration Commands.** The following signals shall be sent to the electronic calibrator. The electronics calibration sequence (software-controlled) shall consist of 9 scan lines, with each line corresponding to a single ECAL level. The ECALCLK signal shall be supplied continuously .

3.4.13.2.5.1 **Electronic Calibration Level (ECALEVL).** The signal level shall be sent to the optics module through the optics port. The ECAL circuit level selection shall be coded 00H..07H.

3.4.13.2.5.2 **Electronic Calibration Enable (ECALEN).** The enable signal shall be sent through the optics-bus. The enable condition shall be high true.

3.4.13.2.5.3 **Electronic Calibration Chopper Drive (ECALCLK).** The electronic calibration voltage shall be chopped by ECALCLK, having the same timing as the accumulator control signals (See Figure 9). There are two down and one up periods for each chopper slot as shown in Figure 8, with two slots per color for each chopper revolution. The timing shall be determined by counting down the VFC Reference Clock, starting from the trailing edge of the Phase Reference Pulse, delayed by up to 500 VFC clock pulses by a separately adjustable delay. A different delay is required because the calibration signals are applied in front of the electronics and therefore must occur earlier by a time equal to the delay of the electrometers and amplifiers. The relative timing of the slot edges shall be as specified in Table 29 (0.003 degrees of rotation = 1 VFCCLK period).

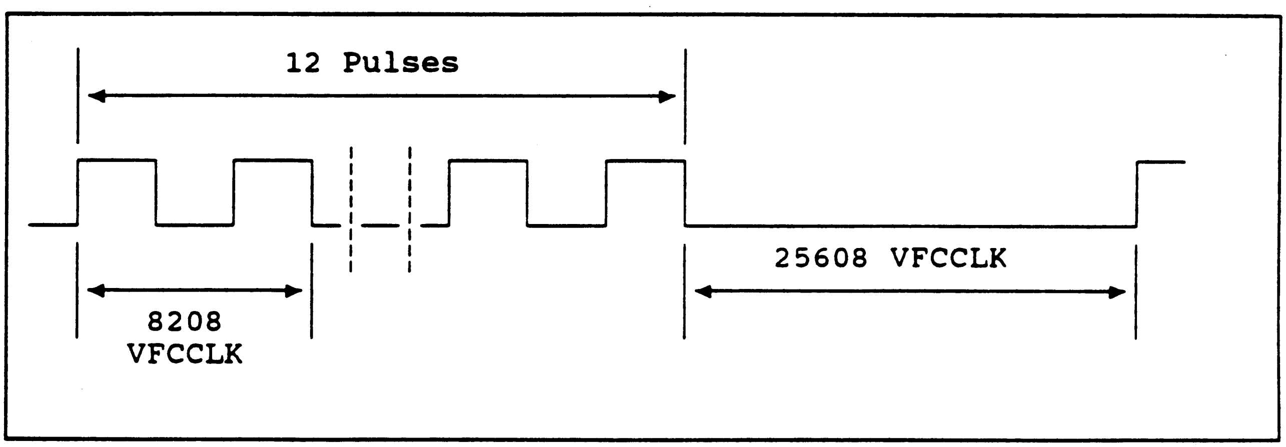

Figure 9. ECALCLKL Signal (with ECALENBL High)

3.4.13.3 **Subsystem Inputs from Optics Module.** The interface subsystem shall receive the signals listed below besides those listed in Tables 30 and 31.

3.4.13.3.1 **Photodetector VFC Inputs.** Three signals VFCRNG1, VFCRNG2 and VFCRNG3 shall be received. These signals shall be synchronous with VFCCLK (see Table 33) with a maximum delay of 0.25 microseconds and with 10-90 percent rise and fall times of 0.2 microseconds or less. The average number of pulses present (high true) is proportional to detected signal current.

3.4.13.3.2 **Housekeeping VFC Input.** The HKVFC signal shall be synchronous with VFCCLK with a maximum delay of 0.25 microseconds and with 10-90 percent rise and fall times of 0.2 microseconds or less. The average number of pulses present (high true) is proportional to detected signal voltage.

3.4.13.3.4 **Passive Analog Telemetry.** Two wires from each of 7 thermistors shall pass out to the spacecraft interface.

3.4.13.4 **Signal Processing.** The subsystem shall process the signals as follows.

3.4.13.4.1 **Photodetector Synchronous Demodulation and Accumulation.** Synchronous demodulation shall be based on a program of 120,000 counts per chopper revolution. Counts from each VFC shall be accumulated for each wavelength band. Counts in the down and up periods shall be accumulated separately and subtracted as required. There are two down and one up periods for each chopper slot as shown in Figure 8, with two slots per color for each chopper revolution. The timing for the demodulation shall be determined by counting down the VFC Reference Clock, starting from the trailing edge of the Chopper Phase Reference (same nominal time as PRP trailing edge), delayed by up to 1023 clock pulses (the maximum delay is about 3.1 degrees in chopper rotation). The relative timing of the slot edges shall be as specified in Table 29.

3.4.13.4.2 **Housekeeping VFC Signal Accumulation.** The housekeeping signals shall be accumulated by the processor in a 12-bit accumulator. Four samples shall be taken during the retrace time of the scan mechanism, increasing the housekeeping channel by 1 (module 32) for each sample with a minimum range of 12 bits. The value in the accumulator shall be saved in the array element indicated by the current housekeeping subcom address.

3.4.13.5 **Outputs to Motor/Heater Driver (MHD).** The interface subsystem shall generate the signals listed below.

3.4.13.5.1 **Scanner Step Commands.** The scanner shall be stepped at the trailing edge of the Chopper Phase Reference clock. Timing is uncritical and may be interrupt-driven. Step and enable signals shall be generated to operate the scan motor drive circuits. The 3-bit motor state and absolute motor position shall be tracked by the processor and updated for each step. In retrace, the phase reference shall be disregarded and the motor stepped at a constant rate of 50 steps per second. Note that the number of scan and retrace steps is one less than the number of scan positions.

3.4.13.5.2 **Diffuser Step Commands.** When enabled, the diffuser carousel positioning motor shall be stepped at a constant rate of 25 Hz. Timing is uncritical and may be interrupt-driven. The carousel position encoder shall be sampled within 1 millisecond before the next step is due. The 3-bit motor state and absolute motor position shall be tracked by the processor and updated for each step. The motor shall be disabled when the commanded encoder position is reached.

3.4.13.6 **Processor Hardware Characteristics.** The critical characteristics of the processor shall be as follows.

3.4.13.6.1 **Clock Rate.** The processor shall be synchronized with the 12 MHz master oscillator used to generate VFCCLK. Operating frequency shall be derated in accordance with PPL-19 Appendix B.

3.4.13.6.2 **Watchdog Timer.** The processor shall be equipped with a watchdog timer that shall reset the processor if not continually updated. The watchdog timer shall time out in one scan line or less.

3.4.13.6.3 **Peripheral Readback.** All memory elements such as registers, timers, etc shall be capable of readback for checking single event upset, or else shall be refreshed.

3.4.13.7 **Processor Software Characteristics.** The critical characteristics of the software system shall be as follows.

3.4.13.7.1 **Error Handling.** The processor shall at least detect the error conditions listed in Table 11 and handle them as specified below.

3.4.13.7.1.1 **Error Codes.** Error codes shall be in accordance with Table 11. Other errors added to this list shall be documented in the software design specification and instrument manuals.

3.4.13.7.1.2 **Error Logging.** The processor shall maintain an error stack of at least 16 8-bit error codes. The error code on the top of the FIFO buffer shall be transmitted in the digital status data record.

3.4.13.7.1.3 **Error Response.** Errors shall be classified as fatal or non-fatal. Fatal errors shall cause a warm start. If a data error occurs the current data packet shall be flagged invalid. An error code of zero shall indicate normal operation.

3.4.13.7.1.4 **Timer Interrupt Error (Fatal).** Failure of the principal timing interrupt to occur within a timing window shall generate a fatal error.

3.4.13.7.1.5 **Illegal Interrupt (Fatal).** All interrupt vectors shall be coded so that if an unused interrupt occurs a fatal error shall be generated.

3.4.13.7.1.6 **Improper Code Sequence (Fatal).** Unused code space shall be coded so that a jump to that space results in a fatal error.

3.4.13.7.1.7 **Command ID Error (Non-Fatal).** The processor shall check the validity of all serial commands. If an invalid command is detected an error code shall be placed on the error stack and command shall be disregarded. If a valid command is detected, the processor shall enter the commanded mode using the parameters uploaded in the command, if any.

3.4.13.7.1.8 **Command Sequence Error (Non-Fatal).** An error shall be recorded and the command rejected if the command parameter words are in an incorrect sequence (parameter word without command ID word).

3.4.13.7.1.9 **Command Data Error (Non-Fatal).** The processor shall check the validity of all uploaded parameters. If the data is meaningless or out of range an error code shall be placed on the error stack and the command disregarded.

3.4.13.7.1.10 **Command Register Overflow (Non-Fatal).** An error shall be generated if more command bits are sent than the command register will hold.

3.4.13.7.1.11 **Command Queue Overflow (Non-Fatal).** An error shall be generated if more commands are sent than the command queue will hold.

3.4.13.7.1.12 **Telemetry Register Underflow (Non-Fatal).** An error shall be generated if the data register is not fully shifted out.

3.4.13.7.1.13 **Reset (Non-Fatal).** The processor shall check the status of all mechanisms and reset to unloaded Mode with default parameters stored in ROM. The reset error code shall be generated. This error is non-fatal because it reports the existence of a previous fatal error. The orbit clock shall not be reset.

3.4.13.7.1.14 **Memory Errors.** Errors shall be generated when incorrect memory operation is detected (memory verification fails).

3.4.13.7.1.15 **Mechanism Response Error (Fatal).** The processor shall maintain backup counts for all mechanism positions to be compared with encoder readouts. If an encoder does not reach the expected state an error shall be generated and the mechanism repositioned to a reference position. A window shall be maintained for PRP timing verification; if the PRP does not occur in the expected window an error shall be generated and data flagged invalid.

3.4.13.7.1.16 **Backup Timeout Error (Non-Fatal).** All operations involving a wait for a status condition or interrupt shall have backup timeouts.

3.4.13.7.1.17 **Data Overrun and Underrun Errors (Non-Fatal).** Errors shall be generated if the spacecraft does not read data often enough, so that data storage capacity is exceeded. The data validity flag shall be set false and the data set to zero if data is requested before it is ready.

3.4.13.7.1.18 **Register Errors (Non-Fatal).** An error shall be recorded when an instrument register is read back and found to have an incorrect value.

3.4.13.7.2 **Mechanism, Lamp, and High-Voltage Enable/Disable.** Mechanisms and lamps shall be independently controllable only in Direct Control Mode.

3.4.13.7.3 **Register Refresh.** The processor shall continually check the status of latches and registers or refresh them. There shall be no latch in the system which cannot be verified unless it is continually updated or operates in a self-resetting way (a free-running counter, for example)

3.4.13.7.4 **Data Storage.** At least two scan lines of data shall be stored, including all status and housekeeping data and packet headers.

3.4.13.7.5 **Watchdog Timer Update Rate.** The watchdog timer shall be refreshed at least once each chopper cycle.

3.4.14 **Power and Driver Subsystem.** This subsystem shall contain the discrete command relays (if used), the low-voltage power supply, the heater control circuits, and the motor drivers.

3.4.14.1 **Low-Voltage Power Supply.** The power supply shall be designed to operate from the input bus whose characteristics are stated in the power interface specifications and to meet the electromagnetic compatibility specifications herein. The output characteristics of the main power supply shall be as shown in Table 34. Precision references, where needed, shall be generated at the point of use. Outputs shown with different ground symbols shall be connected at only one point. This shall be the instrument star ground, connected to spacecraft digital signal ground, except that the optics +5V ground GL2 shall be connected to the ±12V ground only near the voltage-to-frequency converters.

Table 34. Power Supply Output Requirements
Ground column identifies isolated returns

Function	Voltage (V)	Noise + Ripple (mV_p)	Regulation (mV)	Ground	Max Output Current (A)
Logic power (electronics)	+5	100	±100	5VLRTN	0.44
Logic power (optics)	+5	100	±50	5VARTN	0.10
Analog power	+12.5	125	± 125	12VRTN	0.30
Analog power	-12.5	125	±125	12VRTN	0.15
Motor and heater power 1/	+24.5	735	±735	24VRTN	1.0
High voltage power bus	+36.7	---	±1100	36VRTN	0.02
Spacecraft interface	+10.0	400	±1000	5VLRTN	0.04

1/ The total of 24.5 V assumes load sharing.

3.4.14.2 **Dynamic Cross Regulation.** When the output current of the +24.5 V output jumps between 0.4 A and 0.9 A, a 0.5 A load current step, at 50% duty cycle and a repetition rate of 100 Hz, the output voltage dip and surge on the +12.5 V and -12.5 V outputs due to this load current step shall be less than 80 mV.

3.4.14.3 **Stepping Motor Drivers.** The stepping motor drivers shall drive the stepping scanner and diffuser mechanisms listed above.

3.4.14.3.1 **Motor Connection.** Motors shall be Y-connected, center open (and unavailable), driven by shielded twisted triple. Current and impedance levels shall be in accordance with the specifications of the respective subsystems above.

3.4.14.3.2 **Stepping Motor Drive Signals.** The motor drive circuit shall consist of a 3-phase 6—switch bridge driven by four logic-level signals (Phase 1,2,3). The logic signals shall be generated by the processor and be latched in a parallel port. A logic low on the enable input shall disconnect all bridge switches. The drive sequence shall be as shown in Table 36. Motion shall be clockwise when viewed from the output shaft when driven with the forward code sequence.

3.4.14.3.3 **Motor Drive Pulse Hold Duration.** The stepping motor current pulse duration shall be 32 $\pm$ 1 milliseconds or the step period, whichever is less.

3.4.14.3.4 **Not used.**

Table 36. Stepping Motor Drive Sequence 3-Phase Y-Connected Center Open, 6-Switch Bridge Drive H=High, L=Low, X=Open			
Forward (CW)		Reverse (CCW)	
Step (Mod 6)	Bridge Output Ph 1 Ph 2 Ph 3	Step (Mod 6)	Bridge Output Ph 1 Ph 2 Ph 3
0	H L L	5	H H L
1	H L H	4	L H L
2	L L H	3	L H H
3	L H H	2	L L H
4	L H L	1	H L H
5	H H L	0	H L L
Disable	X X X	Disable	X X X

3.4.15 **Thermal Control Subsystem.** The thermal control subsystem shall control the TOMS subsystem operating temperatures in accordance with Table 37 in the TOMS orbital environment with the spacecraft thermal interfaces defined above. Separate heaters may be used as necessary to control the monochromator flange, lower housing (with PMT as the reference). The total number of operational heaters shall not exceed 4, excluding the lamp and diffuser heaters. The PMT heater control system shall have a limit cycle of ±0.1 °C or less. Lamp and diffuser heater requirements shall be as defined in the applicable paragraphs above. Survival heaters shall keep the instrument in the -10°C to +30°C temperature range when the TOMS power is off.

Table 37. Thermal Subsystem Operating Temperature Control Requirements (°C)			
Subsystem/Area	Initial	Orbital Var'n	Over Life
Photomultiplier	20±1	±0.2	±1
Lower Housing Assembly	20±5	±2	±3
Monochromator Flange	20±2	±2	±3
Monochromator Differential	0±0.1	±0.2	±0.2
Pedestal-Mounted Electronics	-10 to +30	-10 to +30	-10 to +30

3.4.16 **Instrument Housing.** The instrument housing shall support the instrument components in the specified environments and maintain the measured alignment accuracy with the spacecraft and the specified alignments between subsystems. Ports and access shall be provided for test and adjustment operations.

3.5 **Qualification.** TOMS FM-3 shall be a protoflight model and shall pass the qualification-level environmental tests as specified herein.

4. **PRODUCT ASSURANCE.**

4.1 **Product Assurance Provisions.** The product assurance program shall be conducted in accordance with the provisions of 74-0023, in conformity with the requirements of GSFC 303-TOMS-002. TOMS configuration management shall be in accordance with 74-0024.

4.1.1 **Responsibility.** Perkin-Elmer shall be responsible for product assurance activities in accordance with the 74-0023.

4.1.2 **Access for Government Representatives.** Access for government representatives shall be provided as required by GSFC 303-TOMS-002.

4.1.3 **Special Tests and Examinations.** Tests and examinations shall be conducted according to the cross-reference matrix in Table 38, which lists all tests including those tests performed only for design verification or qualification. Unless otherwise specified, characteristics of major components shall be verified at lower levels of assembly in accordance with the verification provisions of the subtier specifications referenced in Table 4.

4.2 **Quality Conformance Inspections.**

4.2.1 **Item Definition and Interface.**

4.2.1.1 **Item Definition (Configuration and Nomenclature).** Drawings, specifications and lists shall be inspected for nomenclature consistent with this specification.

4.2.1.2 **Interfaces.** Verification of spacecraft interfaces shall be as specified in section 3.1.2. Verification of internal interfaces shall be performed as specified below according to released test and integration procedures.

4.2.2 **Characteristics Verification.** The TOMS shall meet or exceed the characteristics specified in section 3.2 above when verified in accordance with the method specified below.

4.2.2.1 **Satellite Orbit Characteristics**. The compatibility of the scan program and the wavelength scan frequency with the specified orbit timing shall be verified by analysis.

4.2.2.2 **Primary Operational and Launch Modes.** Proper sequence and function in each mode shall be verified by operating the instrument, observing the mechanism functions, and reviewing the telemetered data. Launch Mode shall be tested by placing the instrument in Standby Mode and turning the power off. Mechanisms should remain in safe positions.

4.2.2.3 **Instrument Parameters.** The behavior of the instrument shall be observed to verify that the operation is consistent and the telemetered values agree with the fixed or commanded parameters. All parameter uploads shall be checked to verify that out-of-range parameters are rejected.

4.2.2.4 **Relay Commands.** Operation of command relays and the function controlled shall be verified. The bilevel telemetry outputs shall correctly indicate the state of each relay, with the signal levels prescribed in 3.1.2.6.3.

4.2.2.5 **Emergency Off Warning.** This discrete command input shall be stimulated and instrument shall enter Standby Mode with all mechanisms stowed within the time limit.

4.2.2.6 **Reboot Microprocessor.** This discrete command input shall be stimulated and the microprocessor shall execute the warm start sequence.

4.2.2.7 **Serial Commands.** Serial command format shall be as specified in 3.1.2.6.2. Command response shall be verified in software testing, at the interface subsystem level, and at the instrument level. The TOMS shall be sent each command and the response shall be verified along with the values of any uploaded parameters. Illegal commands with unused or conflicting codes shall also be sent. All possible commands shall be tested and it shall be verified that the instrument rejects all illegal commands with the appropriate error message.

4.2.2.8 **Output Data.** Data format and content shall be verified in software testing, at the interface subsystem level, and at the instrument level. Testing shall verify that stimulation of each data source is correctly reflected in the output data.

4.2.2.9 **Orbit Clock.** The orbit clock shall be measured at a test point for a period of 220 minutes with a precision counter-timer to verify the clock stability. The numerical output in the digital data stream shall be consistent with this measurement. Note that the time of receipt of a data packet is not the time at which it was taken.

4.2.2.10 **Serial Data.** Data formats shall be compared with the logical formats specified above and the physical formats specified in 3.1.2.7.

4.2.2.11 **Spatial Scanning.** The coverage shall be verified by analysis to show that the scan program meets the coverage requirements. The scanner shall be tested to show that it follows the intended program and scans in the specified direction, and that it can step to all encoder positions including reflectance calibration source, diffuser, and stow positions.

4.2.2.12 **Field of View and FOV Registration.** The TOMS field of view shall be measured in directions parallel and perpendicular to the direction of dispersion for each wavelength band. The measurement shall be accomplished by recording the instrument's response to a line source not exceeding 0.15 degrees in angular extent. The measurement shall be made with the scan mirror in the nadir detent and the line source adjusted axially to the approximate center of the field of view. The IFOV, FFOV, and field-of-view registration shall be calculated from the data.

4.2.2.13 **Step Angle, Cross Scan Accuracy, and Scan Repeatability.** The scan motor step size, step location, and repeatability shall be measured at the motor level. The instrument cross scan accuracy shall be measured at the instrument level.

4.2.2.14 **Scan Rate Stability.** The stability of the scan rate shall be measured during the scan at the instrument level using test points connected to the motor step signal.

4.2.2.15 **Scan Encoder.** The scan encoder code shall be checked at the instrument level by recording the encoder output with the scanner position in single-step mode.

Table 38. Verification Cross-Reference Matrix
I=Inspection, A=Analysis, T=Test, F=Protoflight or Flight Only

Characteristic	Characteristic Reference	Verification Reference	I	A	T		F
Instrument Concept	3.1.1.1	4.2.1.1	X				
Functional Block Diagram	3.1.1.2	4.2.1.1	X				
Exploded View	3.1.1.3	4.2.1.1	X				
Interface Characteristics (All)	3.1.2	4.2.1.2	X		X		X
Major Component List	3.1.3	4.2.1.1	X				
Satellite Orbit Characteristics	3.2.1.1	4.2.2.1		X			
Primary Operational Modes	3.2.1.2.1	4.2.2.2			X		
Launch Mode	3.2.1.2.2	4.2.2.2			X		
Instrument Parameters	3.2.1.3	4.2.2.3			X		
Relay	3.2.1.4.1	4.2.2.4			X		
Emergency Off	3.2.1.4.1.6	4.2.2.5			X		
Reboot Microprocessor	3.2.1.4.1.7	4.2.2.6			X		
Serial Commands	3.2.1.4.3	4.2.2.7			X		
Output Data	3.2.1.5	4.2.2.8			X		
Orbit Clock	3.2.1.5.1	4.2.2.9			X		
Bilevel Telemetry Data	3.2.1.5.2	4.2.2.8			X		
Serial Data	3.2.1.5.3	4.2.2.10			X		
Sync Code	3.2.1.5.3.1	4.2.2.8			X		
Analog Data	3.2.1.5.3.2	4.2.2.8			X		
Instrument Status	3.2.1.5.3.3	4.2.2.8			X		
Time Stamp	3.2.1.5.3.4	4.2.2.8			X		
Science Data Structures	3.2.1.5.3.5	4.2.2.8			X		
Passive Analog Telemetry	3.2.1.5.4	4.2.2.8			X		
Active Analog Telemetry	3.2.1.5.5	4.2.2.8			X		
Spatial Scanning	3.2.1.6	4.2.2.11			X		
IFOV	3.2.1.6.1	4.2.2.12			X		
Full Field of View	3.2.1.6.2	4.2.2.12			X		
Clear Field of View	3.2.1.6.3	4.2.2		X	X		
Step Angle	3.2.1.6.4	4.2.2.13			X		
Scan Width	3.2.1.6.5	4.2.2.11			X		

Table 38, Continued
Verification Cross-Reference Matrix
I=Inspection, A=Analysis, T=Test, F=Protoflight or Flight Only

Characteristic	Characteristic Reference	Verification Reference	I	A	T		F
Scan Line Period	3.2.1.6.6	4.2.2.11		X	X		
Cross Scan Accuracy	3.2.1.6.7	4.2.2.13			X		
Scan Rate Stability	3.2.1.6.8	4.2.2.14			X		
Scan Repeatability	3.2.1.6.9	4.2.2.13			X		
Diffuser Look	3.2.1.6.10	4.2.2.11			X		
Source Look	3.2.1.6.11	4.2.2.11			X		
Scanner Stow Position	3.2.1.6.12	4.2.2.11			X		
Scan Encoder	3.2.1.6.13	4.2.2.15			X		
Scan Synchronization	3.2.1.6.14	4.2.2.16			X		
Diffusers	3.2.1.7	4.2.2.17	X				
Diffuser Mounting	3.2.1.7.1	4.2.2.18	X				
Diffuser Heating	3.2.1.7.2	4.2.2.19		X	X		
Diffuser Stray Light	3.2.1.7.3	4.2.2.20			X		
Reflectance Calibrator	3.2.1.7.4	4.2.2.21		X	X		
Spectral Measurements	3.2.1.8	4.2.2.22		X			
Wavelength Range	3.2.1.8.1	4.2.2.22		X			
Wavelength Bands	3.2.1.8.2	4.2.2.22		X			
Wavelength Pairs	3.2.1.8.3	4.2.2.22		X			
Spectral Bandpass	3.2.1.8.4	4.2.2.23			X		
Wavelength Accuracy	3.2.1.8.5	4.2.2.23			X		
Wavelength Stability	3.2.1.8.6	4.2.2.24		X			
Wavelength Scan	3.2.1.8.7	4.2.2.25			X		
Instantaneous Field-of-View Registration	3.2.1.8.7.1	4.2.2.12			X		
Image Motion Compensation	3.2.1.8.7.2	4.2.2.26	X	X			
Wavelength Repeatability Monitor	3.2.1.8.8	4.2.2.27	X	X			
Dynamic Range	3.2.1.9.1	4.2.2.28			X		
Radiometric Linearity	3.2.1.9.2	4.2.2.29			X		
Radiometric Repeatability	3.2.1.9.3	4.2.2.30			X		
Signal-to-Noise Ratio	3.2.1.9.4	4.2.2.31			X		
Spectral Stray Light	3.2.1.9.5	4.2.2.32			X		

Table 38, Continued
Verification Cross-Reference Matrix
I=Inspection, A=Analysis, T=Test, F=Protoflight or Flight Only

Characteristic	Characteristic Reference	Verification Reference	I	A	T		F
Radiometric Resolution	3.2.1.9.6	4.2.2.31			X		
Band-to-Band Crosstalk	3.2.1.9.7	4.2.2.33		X	X		
Dark Current Rejection	3.2.1.9.8	4.2.2.34			X		
Single Event Upsets	3.2.1.9.9	4.2.2.59		X			
Polarization Sensitivity	3.2.1.10	4.2.2.35			X		
Magnetic Field Sensitivity	3.2.1.11	4.2.2.36			X		
Temperature Coefficient of Response	3.2.1.12	4.2.2.37			X		
Mass	3.2.2.1	4.2.2.38	X				
Resonant Frequency	3.2.2.2	4.2.2.39			X		
Uncompensated Angular Momentum	3.2.2.3	4.2.2.40		X			
Power	3.2.2.4	4.2.2.41			X		
Main Heater	3.2.2.4a	4.2.2.41			X		
Diffuser Heater	3.2.2.4b	4.2.2.41			X		
Survival Heater	3.2.2.4c	4.2.2.41			X		
Grounding and Shielding	3.2.2.5	4.2.2.42	X				
Input Power Isolation	3.2.2.5.1	4.2.2.43			X		
Output Power Isolation	3.2.2.5.2	4.2.2.44			X		
Local Shields and Returns	3.2.2.5.3	4.2.2.42	X				
Reliability (Lifetime)	3.2.3	4.2.2.45		X			
Maintainability	3.2.4	4.2.2.46		X			
Transportation, Storage and Handling (Nonoperating)	3.2.5.1	4.2.2.47		X			
Functional Test, Checkout and Prelaunch Operations	3.2.5.2	4.2.2.8	X				
Launch Temperature	3.2.5.3.1	4.2.2.49			X		
Launch Pressure Change	3.2.5.3.2	4.2.2.50		X			
Acoustics	3.2.5.3.3	4.2.2.51		X			
Random Vibration	3.2.5.3.4	4.2.2.52		X	X		
Sinusoidal Vibration	3.2.5.3.5	4.2.2.53		X	X		
Shock	3.2.5.3.6	4.2.2.54			X		
Acceleration	3.2.5.3.7	4.2.2.55		X	X		

Table 38, Continued
Verification Cross-Reference Matrix
I=Inspection, A=Analysis, T=Test, F=Protoflight or Flight Only

Characteristic	Characteristic Reference	Verification Reference	I	A	T		F
Orbital Temperature	3.2.5.4.1	4.2.2.56			X		X
Orbital Pressure	3.2.5.4.2	4.2.2.56		X			
Space Radiation	3.2.5.4.3	4.2.2.57		X			
Orbital Microphonics	3.2.5.4.4	4.2.2.58			X		
Design and Construction	3.3	4.2.3	X				
EEE Parts Selection	3.3.1.1	4.2.3	X				X
Material and Process Control	3.3.1.2	4.2.3	X				X
Electromagnetic Compatibility	3.3.2	4.2.3.1	X		X		
Identification and Marking	3.3.3	4.2.3	X				X
Workmanship	3.3.4	4.2.3	X				X
Hand Soldering	3.3.4.1	4.2.3	X				X
Other Processes	3.3.4.2	4.2.3	X				X
Interchangeability	3.3.5	4.2.3.2	X				X
Safety	3.3.6	4.2.3.3	X				X
Standards of Manufacture	3.3.8	4.2.3	X				X
Cleanliness and Contamination Control	3.3.8.1	4.2.3	X				X
Manufacturing Documentation	3.3.8.2	4.2.3	X				X
Operator Training and Certification	3.3.8.3	4.2.3	X				
Drafting Standards	3.3.9.1	4.2.3.4	X				
Optical Design	3.3.9.2	4.2.3.4	X				
Mechanical Design	3.3.9.3	4.2.3.4	X				
Venting	3.3.9.4	4.2.3.4	X				
Thermal Design	3.3.9.5	4.2.3.4	X				
Radiation Shielding Design	3.3.9.6	4.2.3.4	X				
Electrical Design	3.3.9.7	4.2.3.4	X				
Circuit Decoupling	3.3.9.8	4.2.3.4	X				
Printed Wiring Board Design	3.3.9.9	4.2.3.4	X				
Electrostatic Discharge	3.3.9.10	4.2.3.4	X				
Processor and Logic Design	3.3.9.11	4.2.3.4	X				

Table 38, Continued Verification Cross-Reference Matrix I=Inspection, A=Analysis, T=Test, F=Protoflight or Flight Only							
Characteristic	**Characteristic Reference**	**Verification Reference**	**I**	**A**	**T**		**F**
Software Design	3.3.9.12	4.2.3.5	X				
Long Term Illumination Stab.	3.4.7.2	4.2.2.60		X			
Shipping Containers	5.1	4.2.4	X				
Marking for Shipment and Storage	5.2	4.2.4	X				
Connector Protection	5.3	4.2.4	X				X
Airport Security	5.4	4.2.4	X				
International Shipment	5.6	4.2.4	X				X
Inspections	5.7	4.2.4	X				X

4.2.2.16 **Scan Synchronization.** The scanner motor control signals shall be compared to the Chopper Phase Reference signal to verify the relative timing.

4.2.2.17 **Diffusers.** The number of diffusers shall be verified by inspection and demonstration of the diffuser selection operation.

4.2.2.18 **Diffuser Mounting.** The direction of the active diffuser normal shall be measured with respect to the instrument axes to verify that it agrees with the mounting angle specified in the applicable ICD.

4.2.2.19 **Diffuser Heating.** An analysis shall be performed to determine whether the diffuser temperature is greater than all points in the line of sight. The temperature of the diffuser shall be measured in thermal vacuum testing using the diffuser and housing temperature sensors, which shall be precalibrated at the subassembly level.

4.2.2.20 **Diffuser Stray Light.** Reduction of diffuser stray light shall be demonstrated by an irradiance response test. This test shall be conducted at the system level using an FEL lamp mounted on a fixture to simulate the full range of solar illumination conditions in orbit. Measurement intervals shall not exceed one-half the IFOV width (Nyquist criterion). Data shall be obtained in solar calibration (SCAL) mode for all wavelength bands for the full range of illumination conditions while viewing the diffuser when illuminated and when shadowed by a mask. The test shall demonstrate that the stray light rejection is met for all illumination angles.

4.2.2.21 **Reflectance Calibrator.** The accuracy of the calibrator shall be verified by analysis and specification and testing of components. The function shall be tested at the instrument level to show that the measured intensities are consistent with the analysis of calibrator requirements.

4.2.2.22 **Spectral Measurements, Wavelength Range, Bands, and Pairs.** Compliance with the required configuration shall be established by design review.

4.2.2.23 **Spectral Bandpass and Wavelength Accuracy.** The spectral bandpass shall be measured for each band using a wavelength scanning narrow band source and by monochromator film tests using very low pressure spectral line sources.

4.2.2.24 **Wavelength Stability.** Wavelength stability shall be established by mechanical, optical, and thermal analysis.

4.2.2.25 **Wavelength Scan.** Proper operation of the wavelength scanner (chopper) shall be demonstrated at the instrument level and verified by measuring the relative jitter of the chopper synchronization signals through test points. The effect of the commandable signal demodulator delays on the output digital signal levels shall be measured and recorded.

4.2.2.26 **Image Motion Compensation.** The accuracy of the image motion compensation shall be demonstrated by analysis and by verification that the layout of the chopper is consistent with this specification.

4.2.2.27 **Wavelength Repeatability Monitor.** The accuracy of the wavelength monitor shall be demonstrated by analysis and by drawing review and inspection of the assembly for consistency with the analysis and subtier specifications.

4.2.2.28 **Dynamic Range.** The dynamic range of the system shall be verified by analysis and by tests with sources of known intensity to verify the ranges.

4.2.2.29 **Radiometric Linearity.** The gain of the instrument shall be measured as a function of intensity to obtain a radiometric response calibration. The fit shall be a saturation-type with no offset at low level. The linearity and temperature dependence of the gain may be measured using a combination of constant and chopped light signals. The constant light source shall be adjusted to give various average signal output values, which shall be monitored.

4.2.2.30 **Radiometric Repeatability.** The instrument shall be operated 24 hours apart to demonstrate the required repeatability.

4.2.2.31 **Signal-to-Noise Ratio and Radiometric Resolution.** The instrument shall be illuminated with the minimum radiance at 312.5 nm and shall demonstrate the required signal-to-noise ratio and radiometric resolution.

4.2.2.32 **Spectral Stray Light.** Spectral stray light rejection shall be demonstrated by analysis and by observing the daytime sky with and without blocking filters.

4.2.2.33 **Band-to-Band Crosstalk.** Recovery of the detector and detector circuits when stimulated with the most rapidly-changing expected signals from band to band shall be demonstrated by analysis and testing at the subassembly level. For this test, the photomultiplier shall be illuminated with a pulsed light source (LED or equivalent).

4.2.2.34 **Dark Current Rejection.** The instrument offset shall be measured as a function of temperature with no stimulus. The offset shall not change by more than one quantization interval in any wavelength band.

4.2.2.35 **Polarization Sensitivity.** The sensitivity of the instrument to polarized light shall be measured for all wavelength bands by recording the instrument's response while observing a diffuse source through a linear polarizer of known efficiency. The polarizer shall be rotated through a minimum of 180 degrees and the instrument's response shall be recorded at least every 10 degrees of polarizer rotation. Either the diffuse source shall provide unpolarized light or the test shall be conducted to eliminate any error due to polarization of the source.

4.2.2.36 **Magnetic Field Sensitivity.** The photomultiplier shall be immersed in a 1 gauss field in the X, Y and Z directions and the change in output measured when the field is reversed.

4.2.2.37 **Temperature Coefficient of Response.** When illuminated by a stable light source, the instrument responsivity shall be measured in thermal vacuum environment when the instrument temperature is varied over the operating temperature range.

4.2.2.38 **Mass.** The instrument shall be weighed to establish the mass.

4.2.2.39 **Resonant Frequency.** The instrument shall be subjected to low-level sinusoidal vibration to map the resonances.

4.2.2.40 **Uncompensated Angular Momentum.** The inertia of all rotating components shall be measured or calculated and used to verify the total angular momentum by analysis. Motor suppliers shall provide total internal moment-of-inertia data as part of the end-item data package for each motor.

4.2.2.41 **Power.** Power drawn by the instrument and its heaters shall be measured during thermal vacuum testing at the levels specified herein.

4.2.2.42 **Grounding and Shielding.** Drawings shall be inspected and resistance between ground returns and the chassis shall be measured to establish compliance to section 3.2.2.5 herein.

4.2.2.43 **Input Power Isolation.** The resistance between spacecraft power and instrument output signal returns shall not be less than 1 MΩ.

4.2.2.44 **Output Power Isolation.** The resistance between output returns shall not be less than 1 MΩ as specified in the subtier power supply specification when measured prior to connecting the power supply returns to instrument star ground.

4.2.2.45 **Reliability (Lifetime).** Reliability shall be verified by radiation shielding, trend, and lifetime analyses as provided in GSFC-303-TOMS-002 to demonstrate that the instrument will meet the intended life.

4.2.2.46 **Maintainability.** Compliance with the specified maintainability factors shall be demonstrated by analysis presented at the Critical Design Review.

4.2.2.47 **Transportation, Storage and Handling (Nonoperating).** Analysis of packaging design and standard package test data shall verify that the instrument will not exceed its design loads during transportation.

4.2.2.48 **Functional Test, Checkout and Prelaunch Operations.** The instrument shall not be subjected to environmental conditions exceeding those specified.

4.2.2.49 **Launch Temperature.** The instrument shall be tested for survival over the launch temperature range.

4.2.2.50 **Launch Pressure Change.** Survival of the launch pressure transient shall be established by a venting analysis.

4.2.2.51 **Acoustics.** The instrument shall not suffer any damage and shall operate within specification after being subjected to the equivalent of acoustic levels in Table 24.

4.2.2.52 **Random Vibration.** The instrument shall be not suffer any damage and shall operate within specification after being subjected to the random vibration levels in Table 25.

4.2.2.53 **Sinusoidal Vibration.** The instrument shall be not suffer any damage and shall operate within specification after being subjected to the sinusoidal vibration levels in Table 26.

4.2.2.54 **Shock.** The instrument shall be not suffer any damage and shall operate within specification after being subjected to the shock levels in Table 27.

4.2.2.55 **Acceleration.** The instrument shall be not suffer any damage and shall operate within specification after being subjected to the acceleration levels in Table 28

4.2.2.56 **Orbital Temperature and Pressure.** The instrument shall be tested in thermal vacuum for survival over the non-operating temperature range and subsequent proper operation over the operating or qualification orbital temperature range, as applicable.

4.2.2.57 **Space Radiation.** Verification shall be performed as follows, using the specified safety factor:

a. **Radiation Dose.** Analysis of the expected life of dose-sensitive parts shall be performed as required in GSFC-303-TOMS-002, allowing for shielding as designed (also see life verification above).

b. **Single-Event Upset.** The single event upset rate shall be verified by analysis using peak linear energy transfer spectra, allowing for shielding as designed.

c. **Peak Trapped Flux.** Particle-radiation-induced noise limits shall be verified by analysis of background events seen in the detectors. Lots of optical materials subject to fluorescence and phosphorescence from impurities shall be tested to assure acceptability.

4.2.2.58 **Orbital Microphonic Vibration Levels.** Operation of the instrument mechanisms shall not produce microphonic noise in excess of the specified signal-to-noise ratio.

4.2.2.59 **Single Event Upsets.** An analysis shall be performed to verify that data loss does not exceed the equivalent of one scan per orbit.

4.2.2.60 **Long Term Illumination Stability.** The stability of the ratio of the 296.7 nm illuniation of the two entrance slits shall be verfied by analysis to be stable to $\pm 0.5\%$ over the instrument life.

4.2.3 **Design and Construction.** Quality controls shall be established in accordance within the requirements of GSFC-303-TOMS-002 and the provisions of the Perkin-Elmer PAIP to verify that the specified design and process controls are met.

4.2.3.1 **Electromagnetic Compatibility.** Electromagnetic compatibility testing shall be performed according to the requirements herein.

4.2.3.2 **Interchangeability.** Compliance with interchangeability requirements shall be verified by design review.

4.2.3.3 **Safety.** Compliance with the safety requirements of GSFC 303-TOMS-002 shall be monitored during all phases of instrument development, fabrication, and testing as implemented in 74-0023.

4.2.3.4 **Design Constraints.** Compliance with electrical, mechanical and optical design constraints in GSFC TOMS-920-90-001 and GSFC 303-TOMS-002 shall be verified by prerelease drawing reviews and program milestone design reviews in conformity with the Design Assurance and Reliability requirements of GSFC-303-TOMS-002, as implemented in 74-0023.

4.2.3.5 **Software Design.** Software design and documentation shall comply with all requirements of GSFC 303-TOMS-002 as implemented in 74-0023.

4.2.4 **Preparation for Delivery.** Packaging shall be inspected to verify compliance with the delivery documentation and protection requirements.

5. PREPARATION FOR DELIVERY.

All requirements of this section shall be verified by test, inspection, or analysis.

5.1 **Shipping Containers.** For shipping and storage a special container shall be provided and used for all transport. Within this container TOMS shall be bolted to a multipurpose handling fixture. The instrument and fixture shall be sealed in a dry-nitrogen-purged bag. The instrument shall be protected from excessive vibration and shock loading during shipping by wrapping the fixture in a low outgassing foam material. Accelerometers mounted on the handling fixture shall document the maximum shock load to which the TOMS has been exposed.

The container shall be purged before shipment with dry, clean nitrogen and sealed. All containers shall be designed to be lifted using a fork-lift or be mounted on a pallet so designed. Ground support and test equipment shall be packaged separately from the instrument.

5.2 **Marking for Shipment and Storage.** All interior and exterior enclosures and containers shall be legibly marked with the quantity, item name, part number, buyer's name and address, contract number, and serial number. In addition, each package or container shall be conspicuously marked "U.S. Government Property -- Items for Spaceflight Use".

5.3 **Connector Protection.** All unmated connectors shall be protected by suitable covers at all times during storage or shipment.

5.4 **Airport Security.** Transit liaison shall be arranged by the GSFC Security Officer (Telephone 301-982-2233). Preflight arrangements shall be made to avoid inspection of delicate equipment by untrained personnel. Equipment subject to such damage shall be plainly marked on the exterior of the container. A description of the contents of each container shall be made available to the GSFC Security Officer and to the airport authorities. To insure against damage by inspection, equipment shall be packaged in such a way that it can be safely handled if inspection becomes mandatory.

5.5 **International Shipment.** TOMS shall be shipped internationally by air and within the destination country by air or by normal surface transportation. TOMS shall always be loaded, transported, handled, and unloaded under the supervision of a representative from NASA. TOMS shall be packed in the shipping box in its original condition whenever it is transported between sites.

5.6 **Inspections.** All inspections for Customs, or any other purpose, shall be done in a class 100,000 clean room.

6. **NOTES.**

6.1 **Deleted.**

6.2 **Deleted.**

6.3 **Specification Notes.** The following notes apply to the specifications indicated.

6.3.1 **Instrument Alignment.** The alignment mirrors are placed on the lower housing assembly to avoid tolerance buildup. The scanner must be separately aligned with the nadir direction.

6.3.2 **Scanner Nadir Alignment.** The scanner can be aligned no better than the scan accuracy and repeatability permit.

6.3.3 **Spectral Bandpass.** Analysis shows that the full-width at half maximum is not the parameter that should be controlled; it should be the area of the slit function

$$\Delta\lambda = \int R(\lambda)\, d\lambda,$$

where the transmission R(l) is dimensionless. The variance (or other measure of dispersion) should also be controlled to prevent crosstalk.

6.3.4 **Image Motion Compensation.** The Nimbus TOMS wavelength samples were arranged so that not only did the centroids match exactly, the variance of the sample position matched exactly as well. Four chops were used to make it possible to match the variances. Analysis shows that matching the variances makes no difference in the errors obtained scanning a sinusoidal bar pattern with a period of two IFOVs (Nyquist rate). This means that using four chops per wavelength is unnecessary; two are sufficient.

6.3.5 **Dark Current Rejection and Monitoring**. The purpose of the chopper is not to reject ordinary dark current, which is very small and swamped by other offsets, but to reject radiation-induced dark current which is much larger. The dark current should not increase substantially in the radiation environment expected on any of the missions (at the time of solar maximum); this is basically a shielding requirement, plus a requirement to use low-scintillation glasses. The Nimbus TOMS radiation-resistant design used fused silica for the photomultiplier faceplate and lenses because of its low scintillation efficiency. The "dark current" measured in the diagnostic mode is not dark signal but simply the reference side of the chopped signal, which contains a "light" contribution of about 3 percent.

Most of the "dark current" offset (DC voltage at the electrometer output) is actually just electrometer voltage offset, and much of the dark current actually comes from interdynode leakage, not photocathode current. A special measurement of dark current would require a complex electrometer design that would compromise the main function.

6.3.6 **Radiometric Linearity**. TOMS has several piecewise linear ranges which cover the dynamic range in a quasi-logarithmic fashion. In general, the gain and offset of each range must be known, as well as any correction for nonlinearity of the primary detector. This correction is complex because the signal is chopped and because low-level signals must be divided by the high level signals from the diffuser. To attain the ultimate accuracy these corrections must be made by a detailed algorithm to be given eventually in these notes.

6.3.7 **Scan Code**. This code is an extension of the code used on the Nimbus TOMS. To allow for scanning different scan widths it is centered at nadir and uses all 50 positions available. The following discussion is adapted from the Nimbus TOMS design note by M. McCollum.

Six tracks are required to encode all positions with a full 360 degrees of rotation. Coded outputs are provided for the following positions: Forty-one 3-degree scan positions, left and right stow positions, left and right calibration (diffuser-viewing) positions, and for the five intervening sectors, for a total of 50 positions allowed by the code.

The code is a modified Gray code selected to minimize position ambiguity. Because only one bit is permitted to change state for each step, readout error is limited to one step. An exception is necessary at the nadir position for reasons of redundancy. No codes are repeated.

To eliminate single point failures, two sets of LED's are used, one set of LED's in series illuminates tracks A, B, and C, while another set illuminated tracks D, E, and F. The code provides that at least one bit be true for each set of LED's, except for the reference (nadir) position, which is all zeros. This code has 50 available states. A double failure is required to lose the nadir reference. Two bits change state only on either side of nadir. There is never any ambiguity in practice if there is no attempt to read the encoder on the fly, waiting until after scan motor settling before reading. Use of the Gray code is not essential but is good practice.

6.4 Error Budget Derivation.

6.4.1 **Amplitude Stability.** Because no absolute measurements are being made, the limiting requirement is that for ±1% radiometric repeatability. Effects which limit the reproducibility of readings are mainly thermal drifts in orbit and sensitivity to changing magnetic fields in orbit. Noise presumably averages out, except for chopper jitter which is second-order and creates a bias. Table 40 shows the error budget. The optics temperature coefficients budgeted are larger than the calculated values; the reflectance of an aluminum surface changes about ±100 ppm/°C and the transmittance of a fused silica surface changes only about ±9 ppm/°C. The high voltage power supply is assumed to be driving 9 stages of gain with a feedback resistor tracking of ±50 ppm/°C. It is legitimate to combine these errors in rms fashion because they have random signs and there are many of them.

6.4.2 **Phase Stability.** The TOMS is a synchronously modulated and demodulated so that both amplitude and phase errors are important. Errors influence the radiometric repeatability. For a trapezoidal waveform of period q and rise time q_r in angular units, the signal out of the demodulator relative to a signal zero-peak level of unity is

$$S = (1 - \Theta_r/\Theta)/2.$$

The error in the signal when the modulator and demodulator are out of phase by an angle $\Delta\Theta$ is second-order, given by

$$\Delta S/S = -2\Delta\Theta^2/(\Theta_r \; \Theta \; S).$$

Because this error is second-order, any offset (static error) will increase the jitter, and any zero-mean angular jitter will lead to an offset, so that it is not allowable to average the signal. For the TOMS chopper, the rise angle Θ_r is 20.7 milliradians and the slot period is 430 milliradians.

The rms value of the fractional random error in signal is

$$\sigma^2(\Delta S/S) = 8\sigma_j^2(2\Delta\Theta_s^2 + \sigma_j^2)/(\Theta_r\ \Theta\ S)^2.$$

Setting the drift plus static error $\Delta\Theta$ sequel to the phase jitter σ_j, we can solve for the required static error plus drift (or jitter) as follows:

$$\Delta\Theta_s = 0.45\ (\sigma\Theta_r\ \Theta\ S)^{1/2}$$

This equation determines the short-term stability required for ozone pair calibration; it does not apply to the 360 nm reflectance channel, which also has a stability term. The specification calls for a radiometric repeatability of ±1 percent and a diffuser pair calibration trend error of ±0.1 percent per year. The first specification governs the response to orbital temperature variations, while the second specification governs the short-term stability during reflectance calibration, which is also affected by long-term chopper phase drift because the error is second-order. The second specification is more stringent. Taking a short term-stability (jitter) requirement of ±0.02 percent allocable to the phase error, we obtain total error budgets of 0.300 microradians (7.2 microseconds at 797 km) for static error and drift separately, and 600 microradians (14.2 microseconds at 797 km) for rms jitter.

Table 40. Error Budget for Radiometric Repeatability

Parameter	Valve	Units	Error, ppm	Notes
Required Repeatability	10000	ppm	10000	
Temperature variation in orbit	0.5	°C		
Optics temp coefficient				
- Entrance optics	300	ppm/°C	150	Analysis
- Monochromator & exit optics	600	ppm/°C	300	Analysis
Electronics temp coefficient				
- PMT temp coefficient	15000	ppm/°C	7500	Spec
- HVPS gain temp coefficient	60	ppm/°C	450	9x50 ppm
- Electrometer temp coefficient	500	ppm/°C	250	Budget
- VFC temp coefficient	100	ppm/°C	250	Budget
Chopper phase drift	200	ppm/°C	250	Budget
Magnetic field effect	500	ppm	500	Budget
RMS error			7550	
RMS/requirement			0.76	
Worst-case error			9650	
Worst-case/requirement			0.97	

10. APPENDICES.

10.1 **Interconnection List.** Interfaces between the components of the TOMS shall be as defined below. All specified types of connectors are as they appear on the TOMS components. To prevent crosstalk, wire bundles in the instrument and test cable shall be shielded as shown in each of the following tables (all power lines within single power shield, etc). The overall cable shield shall be connected to chassis ground through pin 1 of each connector. All internal shields shall be connected to instrument grounds as noted.

10.1.1 **Spacecraft Interface.** The details of the spacecraft interface shall be as specified in Tables 41, 42, 43, 44 and 45. The signals defined in these tables must meet all electrical characteristics in sections 3.1.2.5 through 3.1.2.8 of this specification.

The TOMS-Spacecraft harness shall not provide wires for connecting to the spare pins of the TOMS-Spacecraft interface connectors.

The chassis pins on the interface connectors shall be connected to theouter shield of the TOMS-Spacecraft harness, and in turn be connected to the spacecraft chassis at the spacecraft side of the interface.

10.1.2 **Optics Module Electronics Module Interface.** The ELM-OPM Interface shall be as specified in the TOMS Electronic Module General Design Specification, 71-0092.

10.1.3 **Test Connectors.** Test connectors shall be provided on the analog and digital interface assemblies as specified in Tables 46 and 47. All signals shall be isolated by a series resistance of at least 10K located at the source.

Table 41. TOMS (Motor/Heater Driver) to S/C Power Interface Unit Interface J1. Male Connector. 25-pin D Subminiature					
Pin	Sig Name	Description	Destination	Gauge Wire	Information
1	SCPWRA	SC Pri Pwr A	EPS	24 min	
2	SCPWRA	SC Pri Pwr A	EPS	24 min	VFC Output
3	SPARE	Spare			VFC Output
4	SPARE	Spare			
5	SCPWRB	SC Pri Pwr B	EPS	24 min	
6	SCPWRB	SC Pri Pwr B	EPS	24 min	
7	SPARE	Spare			
8	SPARE	Spare			
9	SPARE	Spare			
10	FUSETP1	Fuse Testpoint 1	NONE		Inst Pwe Pri Fuse Test
11	FUSETP2	Fuse Testpoint 2	NONE		Inst Pwr Red Fuse Test
12	FUSETP3	Fuse Testpoint 3	NONE		Survival Pwe Rri Fuse Test
13	SPARE	Spare			
14	SCPWRTNA	SC Pri Pwr Rtn A	EPS	24 min	VFC Input
15	SCPWRTNA	SC Pri Pwr Rtn A	EPS	24 min	
16	SPARE	Spare			
17	CHGND	Chassis Ground		26 min	
18	SCPWRTNB	Pri Pwr Rtn B	EPS	24 min	
19	SCPWRTNB	Pri Pwr Rtn B	EPS	24 min	
20	CHGND	Chassis Ground		26 min	
21	SPARE	Spare			
22	STARGND	Star Ground	NONE		
23	STARGND	Star Ground	NONE		
24	SPARE	Spare			
25	SPARE	Spare			

Table 42. TOMS (Motor/Heater Driver) to S/C RIU-A and RIU-B Interface J2. Male Connector. 62-pin D Subminiature					
Pin	Sig Name	Description	Destination	Gauge Wire	Information
1	CHGND	Chassis Ground	RIU-A	26 min	
2	MPWRONA	Master Power ON A	RIU-A	26 min	
3	MPWROFFA	Master Power OFF A	RIU-A	26 min	
4	SHTRONA	Survival Heater ON A	RIU-A	26 min	
5	SHTRONA	Survival Heater OFF A	RIU-A	26 min	
6	DHTRONA	Diffuser Heater ON A	RIU-A	26 min	
7	DHTROFFA	Diffuser Heater OFF A	RIU-A	26 min	
8	LOADCMDA	Load Command A	RIU-A	26 min	Spare Command
9	EMOFFA	Emergency Off A	RIU-A	26 min	
10	HVFLTA	High Voltage Flight Command A	RIU-A	26 min	
11	HVTSTA	High Voltage Test Command A	RIU-A	26 min	
12	MPRSTA	Microprocessor Reboot A	RIU-A	26 min	
13	MSEL1A	Memory Select 1 A	RIU-A	26 min	
14	MSEL2A	Memory Select 1 A	RIU-A	26 min	
15	PWRMONA	Power A Monitor	RIU-A	26 min	
16	SHTRMONA	Survival Heater Relay Monitor A	RIU-A	26 min	
17	DHTRMONA	Diffuser Heater Relay Monitor A	RIU-A	26 min	
18	HVFLMONA	High Voltage Flight Relay Monitor A	RIU-A	26 min	
19	MSEL1MONA	Memory Select 1 Monitor A	RIU-A	26 min	
20	RYMONRTN	Relay Monitor Return A	RIU-A	26 min	
21	RYMONRTN	Relay Monitor Return A	RIU-A	26 min	
22	CHGND	Chassis Ground			
23	RYCMDRTN	Relay Command Ground A	RIU-A	26 min	
24	RYCMDRTN	Relay Command Ground A	RIU-A	26 min	
25	RYCMDRTN	Relay Command Ground A	RIU-A	26 min	
26	SPARE	Spare			
27	SPARE	Spare			
28	SPARE	Spare			
29	SPARE	Spare			
30	SPARE	Spare			
31	SPARE	Spare			
32	SPARE	Spare			
33	HVFLMONB	High Voltage Flight Relay Monitor B	RIU-B	26 min	
34	MSEL1MONB	Memory Select 1 Monitor B	RIU-B	26 min	
35	SCPMONA	SC Power MonitorA	RIU-A	26 min	Twisted Shielded Pair
36	SCPMONRTA	SC Power Monitor Return A	RIU-A	26 min	Twisted Shielded Pair
37	SPARE	Spare			
38	RYMONRTNB	Relay Monitor Return B	RIU-B	26 min	
39	RYMONRTNB	Relay Monitro Return B	RIU-B	26 min	
40	RYCMDRTNB	Relay Command Return B	RIU-B	26 min	
41	RYCMDRTNB	Relay Command Return B	RIU-B	26 min	
42	RYCMDRTNB	Relay Command Return B	RIU-B	26 min	
43	CHGND	Chassis Ground			
44	MPWRONB	Master Power ON B	RIU-B	26 min	
45	MPWROFFB	Master Power OFF B	RIU-B	26 min	
46	SHTRONB	Survival Heater ON B	RIU-B	26 min	
47	SHTROFFB	Survival Heater OFF B	RIU-B	26 min	
48	DHTRONB	Diffuser Heater ON B	RIU-B	26 min	
49	DHTROFFB	Diffuser Heater OFF B	RIU-B	26 min	
50	LOADCMDB	Load Command B	RIU-B	26 min	Spare Command
51	EMOFFB	Emergency OFF B	RIU-B	26 min	
52	HVENBLB	High Voltage Enable Command B	RIU-B	26 min	
53	HVDISTB	High Voltage Disable Command B	RIU-B	26 min	
54	MPRSTB	Microporcessor Reset B	RIU-B	26 min	
55	MSEL1B	Memory Select 1 B	RIU-B	26 min	
56	MSEL2B	Memory Select 2 B	RIU-B	26 min	
57	PWRMONB	Power B Monitor	RIU-B	26 min	

Table 42. TOMS (Motor/Heater Driver) to S/C RIU-A and RIU-B Interface J2. Male Connector. 62-pin D Subminiature					
Pin	Sig Name	Description	Destination	Gauge Wire	Information
58	SHTRMONB	Survival Heater Relay Monitor B	RIU-B	26 min	
59	DHTRMONB	Diffuser Heater Relay Monitor B	RIU-B	26 min	
60	SCPMONB	SC Power Monitor B	RIU-B	26 min	Twisted Shielded Pair
61	SCPMONRTB	SC Power Monitor Return B	RIU-B	26 min	Twisted Shielded Pair
62	CHGND	Chassis Ground	RIU-B	26 min	

Table 43. TOMS (Digital I/O) to S/C APX-A and APX-B Interface J6. Male Connector. 15-pin D Subminiature					
Pin	Sig Name	Description	Destination	Gauge Wire	Information
1	CHGND	Chassis Ground			
2	MDCLKA	Mission Data Clock A	AXP-A	26 min	Twisted Shielded Pair
3	MDENA*	Mission Data Enable A (BAR)	AXP-A	26 min	Twisted Shielded Pair
4	MDDATAA	Mission Data A	AXP-A	26 min	Twisted Shielded Pair
5	MDCLKB	Mission Data Clock B	AXP-B	26 min	Twisted Shielded Pair
6	MDENB*	Mission Data Enable B (BAR)	AXP-B	26 min	Twisted Shielded Pair
7	MDDATAB	Mission Data B	AXP-B	26 min	Twisted Shielded Pair
8	SPARE				
9	MDCLKART	Mission Data Clock A Return	AXP-A	26 min	Twisted Shielded Pair
10	MDENART*	Mission Data Enable A (BAR) Return	AXP-A	26 min	Twisted Shielded Pair
11	MDDATAAR	Mission Data A Return	AXP-A	26 min	TWisted Shielded Pair
12	MDCLKBRT	Mission Clock B Return	AXP-B	26 min	Twisted Shielded Pair
13	MDENBRT*	Mission Data Enable B (BAR) Return	AXP-B	26 min	Twisted Shielded Pair
14	MDDATABR	Mission Data B Return	AXP-B	26 min	Twisted Shielded Pair
15	SPARE	Spare			

Table 44. TOMS (Passive Analog) to S/C RIU A and RIU B Interface J10, Male Connector, 50-pin D Subminiature					
Pin	Sig Name	Description	Destination	Gauge Wire	Information
1	SCIST	Spacecraft Interface Survival Temperature	J51	26 min	
2	SCISTRTN	Spacecraft Interface Survival Temp Return	J51	26 min	
3	DHST	Diffuser Housing Survival Temperature	J58	26 min	
4	DHSTRTN	Diffuser Housing Survival Temp Return	J58	26 min	
5	LHFST	Lower Housing Flange Survival Temperature	J56	26 min	
6	LHFSTRTN	Lower Housing Flange Survival Temp Return	J56	26 min	
7	LHST	Lower Housing Survival Temperature	J57	26 min	
8	LHSTRTN	Lower Housing Survival Temp Return	J57	26 min	
9	DIFHTR	Diffuser Heater Power	J58	26 min	
10	DIFHTRTH	Diffuser Heater Thermostat	J58	26 min	
11	SPARE	Spare			
12	LHRST	Lower Housing Radiator Surv Temperature	J34	26 min	
13	LHRSTRTN	Lower Housing Radiator Surv Temp Return	J34	26 min	
14	MYRST	Minus Y RADIATOR SURV TEMPERATURE	J13	26 min	
15	MYRSTRTN	Minus Y RADIATOR SURV TEMP RETURN	J13	26 min	
16	PYRST	Plus Y RADIATOR SURV TEMPERATURE	J12	26 min	
17	PYRSTRTN	Plus Y RADIATOR SURV TEMP RETURN	J12	26 min	
18	SPARE	Spare			
19	SPARE	Spare			
20	SPARE	spare			
21	SPARE	Spare			
22	SPARE	Spare			
23	CHGND	Chassis Ground		26 min	Terminate To Backshell/Chassis
24	SPARE	Spare			
25	PYSHTRTH	Plus Y Survival Heater Thermostat	J51	26 min	
26	MYSHTRTH	Minus Y Survival Heater Thermostat	J51	26 min	
27	MYSHTR	Minus Y Survival Heater Power	J51	26 min	
28	SPARE	Spare			
29	SPARE	Spare			
30	SPARE	Spare			
31	SPARE	Spare			
32	SPARE	Spare			
33	SPARE	Spare			
34	SCIST	Spacecraft Interface Survival Temperature	J10	26 min	Daisy-chain to pin 1
35	SCISTRTN	Spacecraft Interface Surv Temp Return	J10	26 min	Daisy-chain to pin 2
36	DHST	Diffuser Housing Survival Temperature	J10	26 min	Daisy-chain to pin 3
37	DHSTRTN	Diffuser Housing Survival Temp Return	J10	26 min	Daisy-chain to pin 4
38	LHFST	Lower Housing Flange Survival Temperature	J10	26 min	Daisy-chain to pin 5
39	LHFSTRTN	Lower Housing Flange Surv Temp Return	J10	26 min	Daisy-chain to pin 6
40	LHST	Lower Housing Survival Temperature	J10	26 min	Daisy-chain to pin 7
41	LHSTRTN	Lower Housing Survival Temp Return	J10	26 min	Daisy-chain to pin 8
42	SPARE	Spare			
43	LHSHTRTH	Lower Housing Survival Heater Thermostat	J57	26 min	
44	SPARE	Spare			
45	LHRST	Lower Housing RADIATOR SURV TEMPERATURE	J10	26 min	Daisy-chain to pin 12
46	LHRSTRTN	Lower Housing RADIATOR SURV TEMP RETURN	J10	26 min	Daisy-chain to pin 13
47	MYRST	Minus Y RADIATOR SURV TEMPERATURE	J10	26 min	Daisy-chain to pin 14
48	MYRSTRTN	Minus Y RADIATOR SURV TEMP RETURN	J10	26 min	Daisy-chain to pin 15
49	PYRST	Plus Y RADIATOR SURV TEMPERATURE	J10	26 min	Daisy-chain to pin 16
50	PYRSTRTN	Plus Y RADIATOR SURV TEMP RETURN	J10	26 min	Daisy-chain to pin 17

Table 45. TOMS (Digital I/O) to S/C RIU-A and RIU-B Interface J15. Female Connector. 25-pin D Subminiature					
Pin	**Sig Name**	**Description**	**Destination**	**Gauge Wire**	**Information**
1	CHGND	Chassis Ground			
2	CMDCLKA	Command Clock A	RIU-A	26 min	
3	CMDENA	Command Enable A	RIU-A	26 min	
4	CMDDATAA	Commanc Data A	RIU-A	26 min	
5	MNRFRMA	Minor Frame A	RIU-A	26 min	
6	TIMSYNCA	Time Sync A	RIU-A	26 min	
7	CMDCLKB	Command Clock B	RIU-B	26 min	
8	CMDENB	Command Enable B	RIU-B	26 min	
9	CMDDATAB	Command Data B	RIU-B	26 min	
10	MNRFRMB	Minor Frame B	RIU-B	26 min	
11	TIMSYNCB	Time Sync B	RIU-B	26 min	
12	SPARE	Spare			
13	SPARE	Spare			
14	CMDCLKAR	Command Clock A Return	RIU-A	26 min	
15	CMDENART	Command Enable A Return	RIU-A	26 min	
16	CMDDATAR	Command Data A Return	RIU-A	26 min	
17	MNRFRMAR	Minor Frame A Return	RIU-A	26 min	
18	TIMSYNAR	Time Sync A Return	RIU-A	26 min	
19	CMDCLKBR	Command Clock B Return	RIU-B	26 min	
20	CMDENBRT	Command Enable B Return	RIU-B	26 min	
21	CMDDATBR	Command Data B Return	RIU-B	26 min	
22	MNRFRMBR	Minor Frame B Return	RIU-B	26 min	
23	TIMSYNBR	Time Sync B Return	RIU-B	26 min	
24	SIGGND	SIGNAL GROUND			
25	SIGGND	SIGNAL GROUND			

(1), (2), (3), (4): For EP only; each signal pair should be connected together on the S/C side.

Table 46. OPM (Motor Controller Deck) Test Connector, J60, Female Connector, 37-pin D Subminiature Crimp					
Pin	Sig Name	Description	Destination	Gauge Wire	Information
1	TCHREFTP	Tach Reference Testpoint	Test	26 min	1/
2	TCHSIGTP	Tach signal Testpoint	Test	26 min	1/
3	PRPREFTP	PRP Reference Testpoint	Test	26 min	1/
4	PRPSIGTP	PRP Signal Testpoint	Test	26 min	1/
5	CHOPITP	Chopper Motor Current Testpoint	Test	26 min	2/
6	CHPGNDTP	Chopper Signal Ground Testpoint	Test	26 min	
7	SPARE	Spare			
8	SPARE	Spare			
9	SPARE	Spare			
10	SCNATP	Scanner Encoder A Testpoint	Test	26 min	1/
11	SCNBTP	Scanner Encoder B Testpoint	Test	26 min	1/
12	SCNCTP	Scanner Encoder C Testpoint	Test	26 min	1/
13	SCNDTP	Scanner Encoder D Testpoint	Test	26 min	1/
14	SCNETP	Scanner Encoder E Testpoint	Test	26 min	1/
15	SCNFTP	Scanner Encoder F Testpoint	Test	26 min	1/
16	DIFATP	Diffuser Encoder A Testpoint	Test	26 min	1/
17	DIFBTP	Diffuser Encoder B Testpoint	Test	26 min	1/
18	DITCTP	Diffuser Encoder C Testpoint	Test	26 min	1/
19	SPARE	Spare			
20	SPARE	Spare			
21	HVMONTP	High Voltage Monitor Testpoint	Test	26 min	HVMONTP = output voltage/500; 2/
22	RNG1TP	Electrometer Range 1 Testpoint	Test	26 min	3/
23	RNG2TP	Electrometer Range 2 Testpoint	Test	26 min	3/
24	RNG3TP	Electrometer Range 3 Testpoint	Test	26 min	3/
25	ECALTP	ECAL Testpoint	Test	26 min	4/
26	SPARE	Spare			
27	RCALMPTP	RCA Lamp Current Testpoint	Test	26 min	5/
28	WLLMPTP	WL Lamp Current Testpoint	Test	26 min	6/
29	SPARE	Spare			
30	36V	+36 V	Test	26 min	See Table 34
31	12VP	+12 V	Test	26 min	See Table 34
32	12VRTN	12 V Return	Test	26 min	See Table 34
33	12VN	-12 V	Test	26 min	See Table 34
34	5VA	+5 VA Analog	Test	26 min	See Table 34
35	24V	+24 V	Test	26 min	See Table 34
36	SPARE	Spare			
37	SPARE	Spare			

1/ CMOS Type Output; $V_{OL} = 0.1V$ and $V_{OH} = 4.4V$ at $V_{CC} = 4.5V$; 10K isolation resistance.

2/ 0-5.0 ± 0.1V = output voltage; 10K isolation resistance.

3/ 0-7.50 ± 0.15V; 73.1-97.5 Hz; 10K isolation resistance.

4/ 0-8.0 ± 0.16; 73.1-97.5 Hz; 10K isolation resistance.

5/ 0-7.5 ± 0.15V at 333mV/mA; 10K isolation resistance.

6/ 0-7.5 ± 2.5V/mA; 10K isolation resistance.

Table 47. ELM (Digital I/O) Test Connector, J61, Female Connector, 15-pin D Subminiature					
Pin	Sig Name	Description	Destination	Gauge Wire	Information
1	CHGND	Chasis Ground			
2	STEP	Scanner Step command	Test	26 min	1/
3	ORBCLK	Orbit Clock	Test	26 min	1/
4	VFCCLK	VFC Clock	Test	26 min	1/
5	5VL	+5 V Logic	Test	26 min	See Table 34
6	5VLRTN	+5 V Logic Return	Test	26 min	
7	VFCXFR	VFC Transfer	Test	26 min	1/
8	VFCOLR	VFC Color Sync Pulse	Test	26 min	1/
9	VFCTRAN	VFC Transition Sync Pulse	Test	26 min	1/
10	ECALCLK	ECAL Clock	Test	26 min	1/
11	ADATGND	Mission Data Ground	Test	26 min	
12	MDATCLK	Mission Data Clock	Test	26 min	1/
13	MDATEN	MIssion Data Enacle	Test	26 min	1/
14	MDATA	Mission Data	Test	26 min	1/
15	SPARE	Spare	Test		1/

1/ CMOS Type Output; $V_{OL} = 0.1V$ and $V_{OH} = 4.4V$ at $V_{CC} = 4.5V$; 10K isolation resistance.

Table 48. TOMS General Design Specification, 71-0153, Traceability Matrix (sorted per TOMS Technical Spec. paragraph number)		
TOMS GDS Paragraph Number	**Title**	**TOMS Technical Specification Paragraph Number**
3.2.1.8.7.1	Instantaneous Field-of-View Registration	Letter 7/3/91
3.2.1.8.7.2	Image Motion Compensation	Notes 6.3.4; DN 21000-13
3.2.1.9.9	Single-Event Upsets	Letter 7/3/91
3.1	Instrument Definition	3.1.1
3.2.1.1	Satellite Orbit Characteristics	3.1.2
3.2.2.2	Resonant Frequency	3.2.1
3.1.2.2	Mounting and Clear Fields of View	3.2.1
3.1.2.1	Spacecraft Adaptation	3.2.1
3.1.2.3.1	Instrument Alignment	3.2.1
3.1.2.3.2	Scanner Nadir Alignment	3.2.1
3.2.2.1	Mass	3.2.2
3.2.2.4	Power	3.2.3
3.1.2.4	Thermal Interface	3.2.4; 3.6.1
3.2.2.3	Uncompensated Angular Momentum	3.2.6
3.2.1.2.1	Primary Operational Modes	3.3.1
a.	Standby (or light load) (STBY,00H)	3.3.1.a
b.	Scan	3.3.1.b
c.	Solar Calibration (SCAL,02H)	3.3.1.c
d.	Wavelength Monitoring (WMON,03H)	3.3.1.d
e.	Electronic Calibration (ECAL,04H)	3.3.1.d
f.	Diffuser Reflectance Cal. (RCAL,05H)	3.3.1.e
g.	Diagnostic Mode (DM,06H)	3.3.1.f
k.	Direct Control Mode (DC,0AH)	3.3.2
3.2.1.4	Command Functions	3.3.2
3.2.1.4.1.5	High Voltage Enable/Disable	3.3.2
3.2.2.4.1.1	Power On & Off	3.3.2
3.2.1.2.2	Launch Mode	3.3.3
3.3.9.2	Optical Design	3.4.1
3.4.9.2	Long-Term Stability	3.4.1.2; Mod 5 Item 5
3.2.1.6.5	Scan Width	3.4.2.1
3.2.1.6.4	Step Angle	3.4.2.1
3.2.1.6	Spatial Scanning	3.4.2.1
3.2.1.6.1	Instantaneous Half-Power Field of View	3.4.2.2; Mod 5, Item 5
3.2.1.6.7	Scan Accuracy	3.4.2.3
3.2.1.6.8	Scan Rate Stability	3.4.2.3
3.2.1.6.9	Scan Repeatability	3.4.2.3
3.2.1.6.6	Scan Line Period	3.4.2.3; DN 21000-15
3.2.1.10	Polarization Sensitivity	3.4.2.4

Table 48. TOMS General Design Specification, 71-0153, Traceability Matrix (sorted per TOMS Technical Spec. paragraph number)		
TOMS GDS Paragraph Number	Title	TOMS Technical Specification Paragraph Number
3.2.1.7	Diffusers	3.4.2.5
3.2.1.6.10	Diffuser Look	3.4.2.5.1
3.2.1.7.3	Diffuser Stray Light	3.4.2.5.1
3.2.1.7.1	Diffuser Mounting	3.4.2.5.1
3.2.1.7.4	Reflectance Calibrator	3.4.2.5.2
3.2.1.6.11	Source Look	3.4.2.5.2
3.2.1.6.12	Scanner Stow Position	3.4.2.6
3.2.1.8.7	Wavelength Scan	3.4.3
3.2.1.8	Spectral Measurements	3.4.3
3.2.1.6.14	Scan Synchronization	3.4.3
3.2.1.8.1	Wavelength Range	3.4.3.1
3.2.1.8.3	Wavelength Pairs	3.4.3.2
3.2.1.8.2	Wavelength Bands	3.4.3.2; Mod 5 Item 5
3.2.1.8.5	Wavelength Accuracy	3.4.3.3
3.2.1.8.6	Wavelength Stability	3.4.3.4
3.2.1.8.8	Wavelength Repeatability Monitor	3.4.3.5,3.7.9.1
3.2.1.8.4	Spectral Bandpass	3.4.3.6
3.2.1.9.1	Dynamic Range	3.4.3.7
3.2.1.9.2	Radiometric Linearity	3.4.3.8; Notes 6.3.6; DN 21000-14, Letter 7/3/91
3.2.1.9.3	Radiometric Repeatability	3.4.3.9
3.2.1.9.4	Signal-to-Noise Ratio	3.4.3.10
3.2.1.9.5	Spectral Stray Light	3.4.3.11
3.2.1.9.6	Radiometric Resolution	3.4.3.12
3.2.1.11	Magnetic Field Sensitivity	3.4.3.12, Derived
3.2.1.12	Temperature Coefficient of Response	3.4.3.12, Derived
3.2.1.9.7	Band-to-Band Crosstalk	3.4.3.13
3.2.1.9.8	Dark Current Rejection	3.4.3.14; Notes 6.3.5
3.3.9.3	Mechanical Design	3.5
3.2.1.7.2	Diffuser Heating	3.5.3; Letter 7/3/91
3.3.9.7	Electrical Design	3.6
3.2.5.4.1	Temperature	3.6.1
3.2.1.5.3.2	Analog Data	3.7.5
3.2.1.5.3.3	Instrument Status	3.7.5
3.2.1.6.13	Scan Encoder	3.7.5
j.	Upload Memory Mode (UPM,09H)	3.7.6
3.2.1.5.3	Serial Data	3.7.7
3.2.1.5.3.4	Time Stamp	3.7.7

Table 48. TOMS General Design Specification, 71-0153, Traceability Matrix (sorted per TOMS Technical Spec. paragraph number)		
TOMS GDS Paragraph Number	**Title**	**TOMS Technical Specification Paragraph Number**
3.3.2	Electromagnetic Compatibility	3.7.10.4
3.3.9.1	Drafting Standards	3.7.10.6
5.1	Shipping Containers	3.8.6
3.2.4	Maintainability	3.9
6.1	Theoretical Foundations	3.14, Added
3.3.3	Identification and Marking	8.4
3.3.9.9	Printed Wiring Board Design	8.7
3.3.8.2	Manufacturing Documentation	8.7
3.3.8.3	Operator Training and Certification	8.7
3.3.9.10	Electrostatic Discharge	8.8
3.3.8.4	Electrostatic Discharge Control	8.8
3.3.8.1	Cleanliness and Contamination Control	9.0